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16. Abstract Seven textures (transverse tine, transverse broom, artificial turf, transverse roller, artificial-turf/transverse-tine combination, longitudinal tine and longitudinal broom) were formed in the plastic surface of a continuously reinforced concrete pavement. Construction observations indicated that separate machines for texturing and for applying curing compound are preferred since the timing of the two operations is sometimes incompatible. During texturing, care must be taken to avoid overlapping transverse textures, edge damage, and surface deformation caused by the pressure of the device.

Friction tests indicated that grooved textures are superior to broom and artificial-turf textures, with the artificial-turf/transverse-tine combination being the best. A Macrotexture Index, based on both treaded-tire and smooth-tire friction numbers, shows promise as a surrogate texture-depth indicator. The index can determine, with a high degree of certainty, whether a surface has a coarse, medium, or a fine texture. Smoothness tests verified that surface texture can influence Roughness Index values, with transverse-grooved textures being rougher than longitudinal textures. Most motorists can easily detect when they are on the transverse-roller texture, because its wider and deeper 2-inch-spaced grooves result in a humming noise like that produced by rumble strips. The transverse roller texture was eliminated as a final finish candidate because of its noise. During winter storms, natural crosswind and vehicle-generated wind caused blowing snow to collect more on longitudinal-tined and artificial-turf textures than the others.

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State of Illinois
DEPARTMENT OF TRANSPORTATION
Bureau of Materials and Physical Research

A STUDY OF PCC PAVEMENT TEXTURING CHARACTERISTICS IN ILLINOIS

By

Philip G. Dierstein

Final Report

IHR-408

A Research Study Conducted by
Illinois Department of Transportation
in cooperation with
U.S. Department of Transportation
Federal Highway Administration

February 1982

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Feet x 0.3048 - Meters

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A STUDY OF PCC PAVEMENT TEXTURING CHARACTERISTICS IN ILLINOIS

INTRODUCTION

Understanding the role that surface properties play in skid resistance is important to highway engineers because they can exercise some direct and continuing control over them, whereas tire design, vehicle characteristics, and driver behavior are beyond their influence.

When considering surface properties, the friction characteristics derived from them can be separated into two parts: microtexture and macrotexture. In portland cement concrete (PCC), microtexture comes from exposing the sand particles in the mortar. As long as a gritty mortar surface exists, friction numbers (FN) usually range between 45 and 65, but when traffic wear exposes the coarse aggregate, they can drop into the low 20's, depending of course on the type of coarse aggregate and on the amount and the composition of traffic.

Macrotexture (drainage), on the other hand, refers to large-scale roughness such as channels and grooves created by tines, brooms, and turf drags while the concrete is in a plastic state. These channels and grooves help surface water escape from between the tire and the pavement, which is most advantageous at vehicle speeds above 35 mph.

To gain a better understanding about these surface properties, the Division of Highways, in cooperation with the Federal Highway Administration, in 1976 undertook the evaluation of seven textures on Interstate 72, east of Springfield. The results of initial and subsequent tests indicated that the artificial-turf/transverse-tined texture provided the best friction characteristics among the textures examined. This reinforced an earlier decision, made in 1976, to replace the double burlap-drag method of texturing with one requiring an artificial-turf drag followed by transverse tining. A special provision covering this change became effective March 1, 1976 (revised February 1, 1977) to be applied to all rural, high-speed PCC pavement.

Later, after the test results were evaluated, the special provision was incorporated into the Standard Specifications for Road and Bridge Construction adopted October 1, 1979, under Article 408.13.

This report summarizes construction experiences and winter observations, examines the changes in friction, noise, texture, and smoothness that have occurred after three years of service, and evaluates seven surrogate macrotexture indicators.

SUMMARY OF FINDINGS

The major findings and conclusions obtained from this study are summarized below under three separate headings: construction details, winter observations, and test result changes (after 36 months of service).

Construction Details (1)

(1) Using separate machines for texturing and for applying the curing membrane is recommended, since the timing of these two operations is not always compatible (Figure 1).

(2) Overlapping of transverse textures should be avoided because this practice creates an area susceptible to rapid wear (Figure 2).

(3) Longitudinal texturing devices should be raised when the machine stops to prevent deformation of the surface by the pressure of the device (Figure 3).

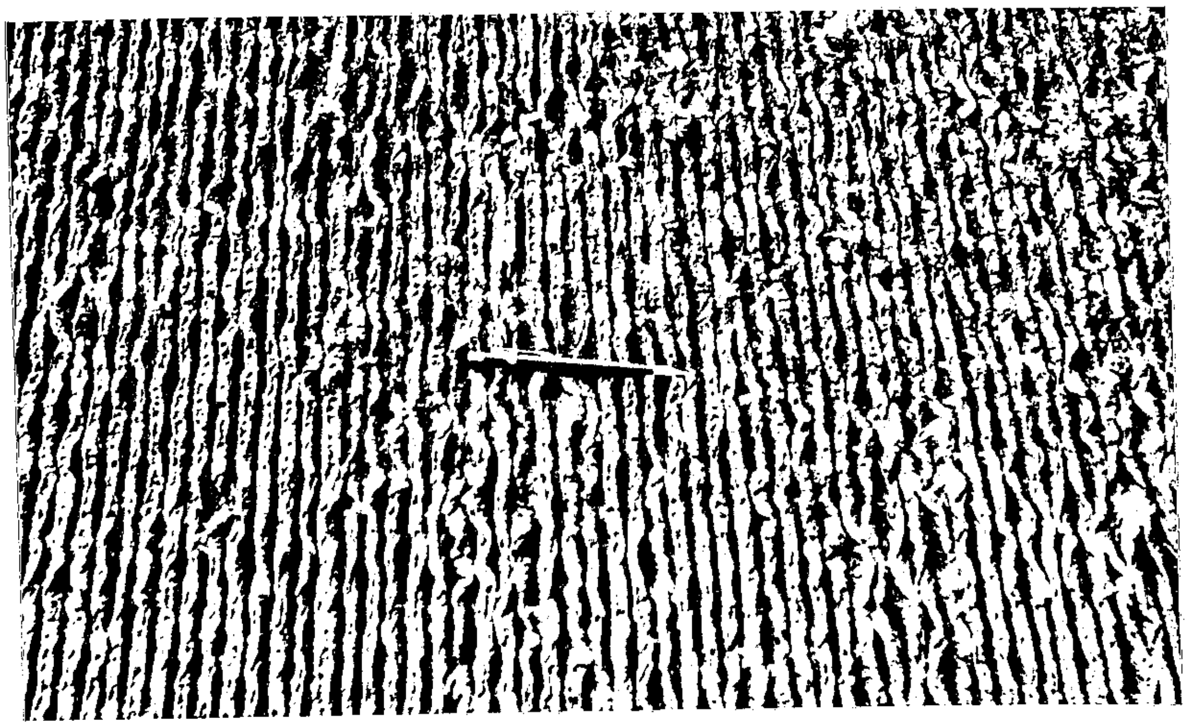


Figure 1. Photograph of artificial-turf/transverse-tine--concrete too wet

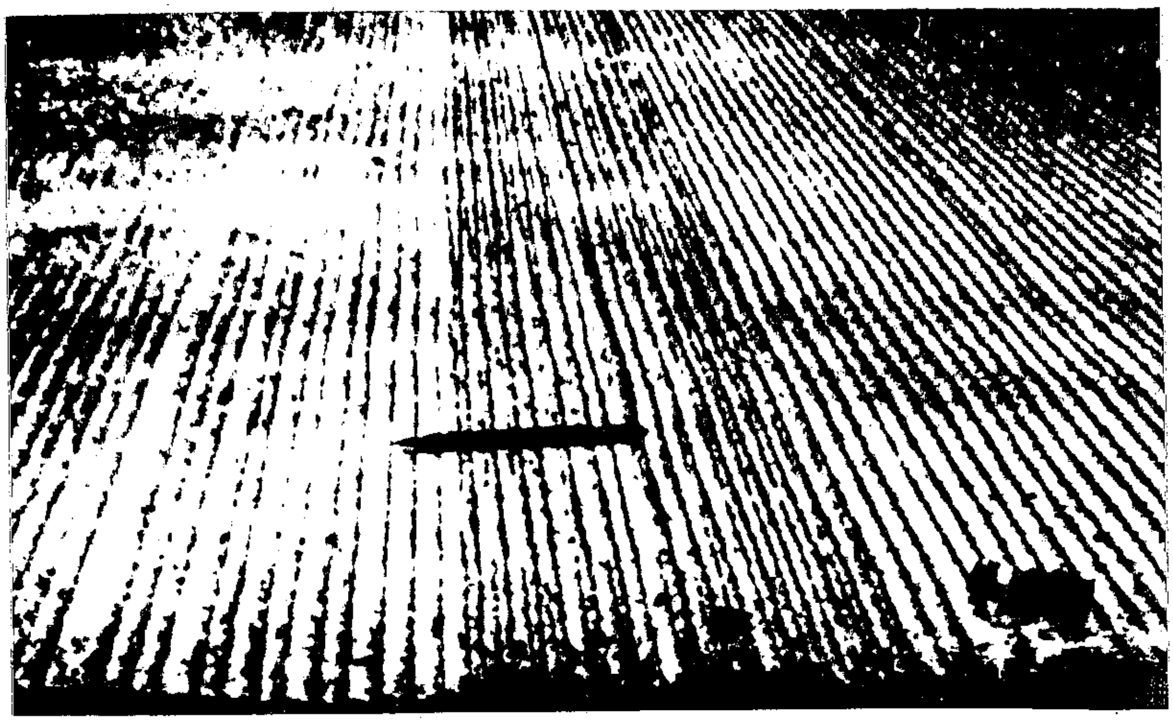


Figure 2. Photograph of overlapped transverse tining

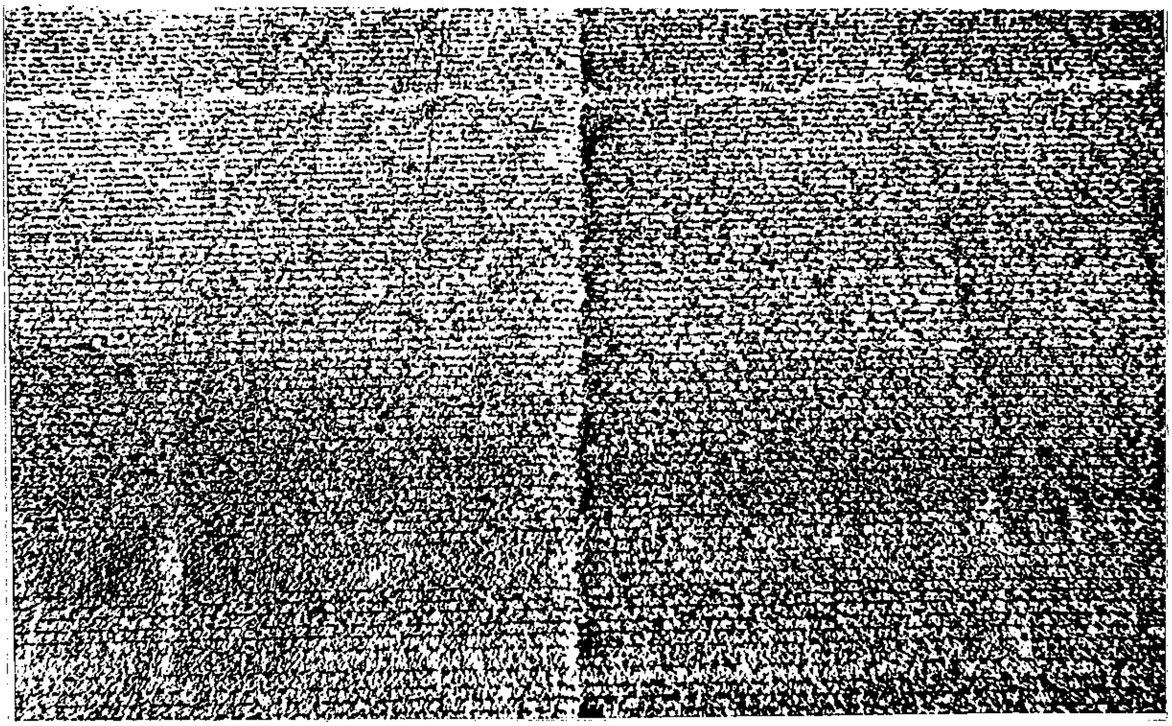


Figure 3. Photograph of depression in longitudinal texture

(4) Special care must be exercised to avoid pavement-edge damage caused by any texturing device (Figure 4).

Winter Observations (1)

(1) Natural crosswind and vehicle-generated wind caused blowing snow to collect more on the longitudinal-tined and the artificial-turf drag textures than the others.

Test Result Changes

(1) The artificial-turf/transverse-tine combination, which initially provided the highest friction number and which was incorporated into the Standard Specifications March 1, 1976, continues to provide the best friction characteristics (both microtexture and macrotexture) among the seven textures being evaluated. Treaded-tire friction numbers ranged initially from a high of 71 for the artificial-turf/transverse-tine combination to a low of 32 for the transverse roller, which had a steel-trowel-like finish. After 36 months of traffic wear, however, the range narrowed considerably between 55 and 49. In contrast to the narrow range for treaded tires, smooth-tire friction numbers ranged from a high of 46 for the artificial-turf/transverse-tine combination to a low of 21 for both the artificial-turf drag and the transverse broom finishes.

These findings led to the conclusion that the ASTM E 501 treaded tire, because of its excellent drainage regardless of the amount of surface macrotexture, lacked sensitivity to the drainage capabilities of the various experimental textures. On the other hand, the ASTM E 524 smooth-tread tire, which has no

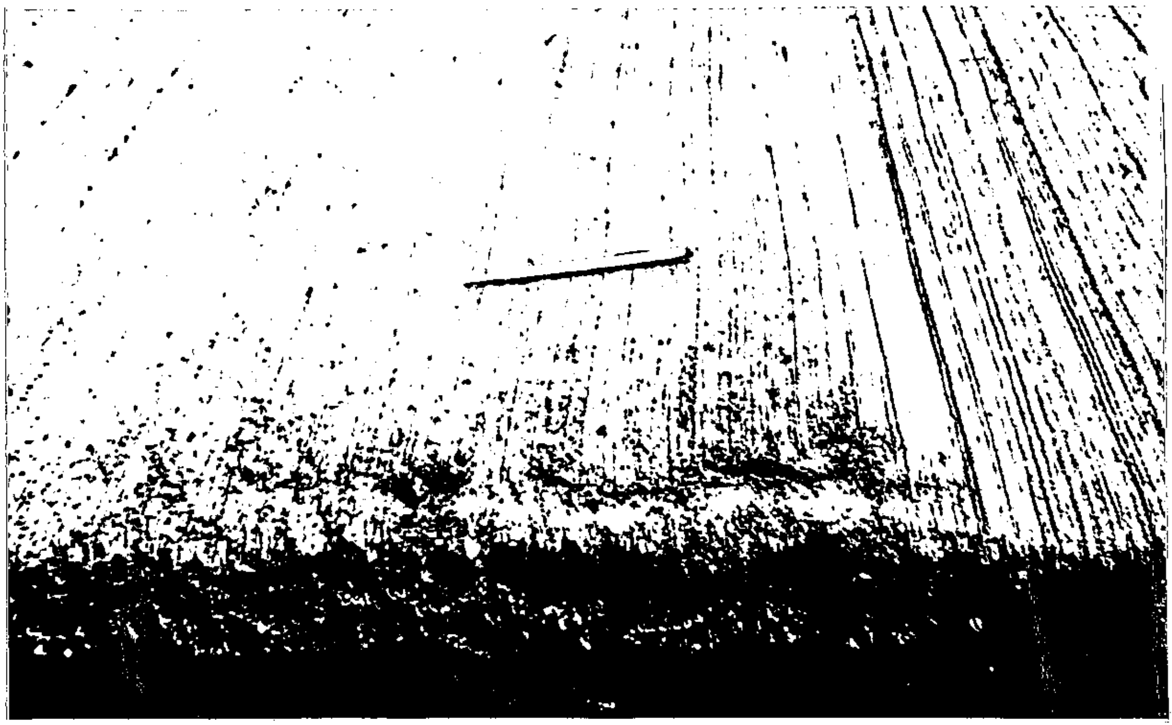


Figure 4. Photograph of edge damage

drainage capabilities, is sensitive to both microtexture and macrotexture.

(2) Friction number-speed gradient changes were associated more with changes in microtexture than with changes in macrotexture. Initially, the gradients were quite steep (0.8 to 1.4), and then flattened (0.3 to 0.6) as friction numbers dropped under traffic wear. Final smooth-tire gradients (0.6 to 0.7) were quite uniform among textures and also were steeper than their corresponding treaded-tire gradients.

(3) A mean sand-patch texture-depth loss of approximately 4 mils occurred after 18 months of traffic, with no measurable loss during the next 18 months. The greatest loss, 14 mils (42%), occurred in the artificial-turf finish while the transverse-roller finish, as might be expected, gave the least loss, 2 mils (11%). An overall increase of 3 mils between the 18- and 36-month measurements was attributed partly to test-operator variance.

(4) Seven macrotexture indicators derived from friction tests were compared to sand-patch texture depth. Of the seven, only four - percent smooth-tire friction number-speed gradient (PFN_sG), smooth-tire friction number (FN_s), treaded-tire minus smooth-tire friction number (FN_{t-s}), and Macrotexture Index $\left[\frac{FN_{t-s}}{FN_{t+s}} + 1\right]$ - correlated well with sand-patch texture depth. Moreover, all four indicators had about the same standard error of estimate (3 to 4 mils) in predicting texture depth.

From the viewpoint of predictability and test efficiency, the Macrotexture Index, based on limited data, showed the greatest promise among the indicators studied as a predictor of texture depth when applied universally to all types of surfaces and over a wide range of friction. Even though some anomalies, attributed in part to the texture-depth measurements themselves, may occur, the index can differentiate with a high degree of certainty whether a surface has a fine, a medium, or a coarse macrotexture.

(5) Smoothness test results verified past experience that surface texture influences Roughness Index values. Before the roadway was opened to traffic, initial Roughness Index values correlated well with sand-patch texture depth. The deep, transverse-grooved finishes ranked above while the longitudinal-tined and the broomed finishes ranked below the artificial-turf (control). Transverse textures gave higher RI values than their corresponding longitudinal textures. As traffic wore away the initial roughness, however, the surfaces became smoother, and the initial RI range narrowed to 7 in./mile from 19 in./mile, causing the strong initial correlation to disappear.

(6) Noise measurements inside a coasting vehicle (engine off, in neutral) were the only ones that could be monitored without bias from the beginning through the end of the study. The initial high (70 dBA) to low (66 dBA) noise-level ranking was as follows: transverse tine, transverse roller, transverse broom, longitudinal tine, artificial-turf (control), longitudinal broom,

and artificial-turf/transverse-tine combination. After 36 months of traffic wear, the initial trend moderated but remained more or less intact except for the transverse-roller texture, whose noise level stands from 4 to 5 dBA above the others. Most motorists can easily detect when they are on the transverse-roller texture, because the wider and deeper 2-inch-spaced grooves, which cause a narrow frequency band of sound, result in a humming noise like that produced by rumble strips. Otherwise, drivers cannot tell when a test section changes.

Obviously, because of noise, the transverse-roller texture was eliminated as a final-finish candidate, but the noise levels of the other textures relative to the artificial-turf (control) were insufficient to rule out their use as a final finish.

STUDY DETAILS

This evaluation of portland cement concrete (PCC) textures was undertaken as a part of Project I-74-1(41)0, Section (84-10-C1, 1SG, 1B-1), Sangamon County. Because of a delay in starting the project (1976 vs. 1975), the Division of Highways agreed in March 1976 to revise its specifications to incorporate a more positive method of providing macrotexture in new PCC pavements before preliminary results from this study were available. A Special Provision for Texturing PCC Pavement, issued at that time, required that the final finish be achieved using an artificial-turf drag followed by transverse tining. Selection of this method was based solely on the experience of other states.

This section identifies the various textures, explains the experimental layout, discusses traffic volumes, outlines the testing program, and reviews changes made to the work plan.

Texture Description

The seven finishes evaluated during this study came from four basic texturing schemes - tining, carpet drag, brooming, and roller grooving.

For tined textures, a metal comb, consisting of spring steel tines spaced at 1/2-inch centers forming approximately 1/8-inch-wide and 1/8- to 3/16-inch-deep grooves, was used in either a longitudinal or a transverse direction.

Carpet-drag textures employed the use of an artificial turf made of molded polyethylene with synthetic-turf blades approximately 0.85 inches long and containing approximately 7,200 individual blades per square foot. The turf carpet extended full pavement width and was of sufficient size that during the finishing operation approximately 2 feet of carpet, parallel to the pavement centerline, was in contact with the pavement surface. The drag was operated in a longitudinal direction.

Broomed finishes were produced both longitudinally and transversely to the pavement centerline. The broom consisted of multiple rows of stiff bristles capable of producing striations of 1/16 inch to 1/8 inch deep.

A metal-roller grooving device produced 1/4-inch-wide by 3/8-inch-deep grooves at 2-inch centers transversely to the pavement centerline.

Photographs of the seven textures can be seen in Figures 5 and 6. The transverse broom, transverse roller, transverse tine, and the artificial-turf/transverse-tine combination are in Figure 5 while the

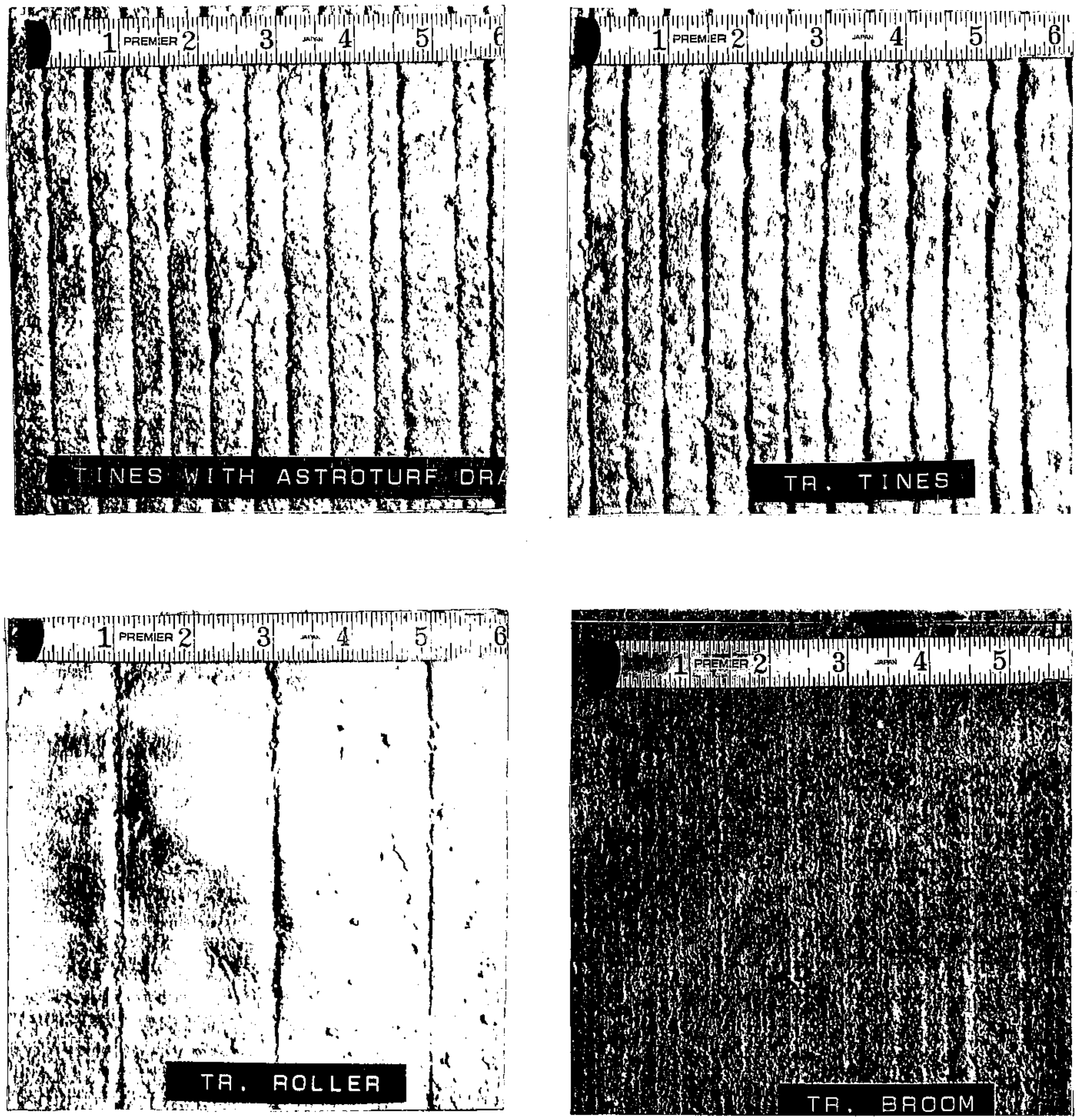


Figure 5. Photograph of Transverse-Textured Surface Castings

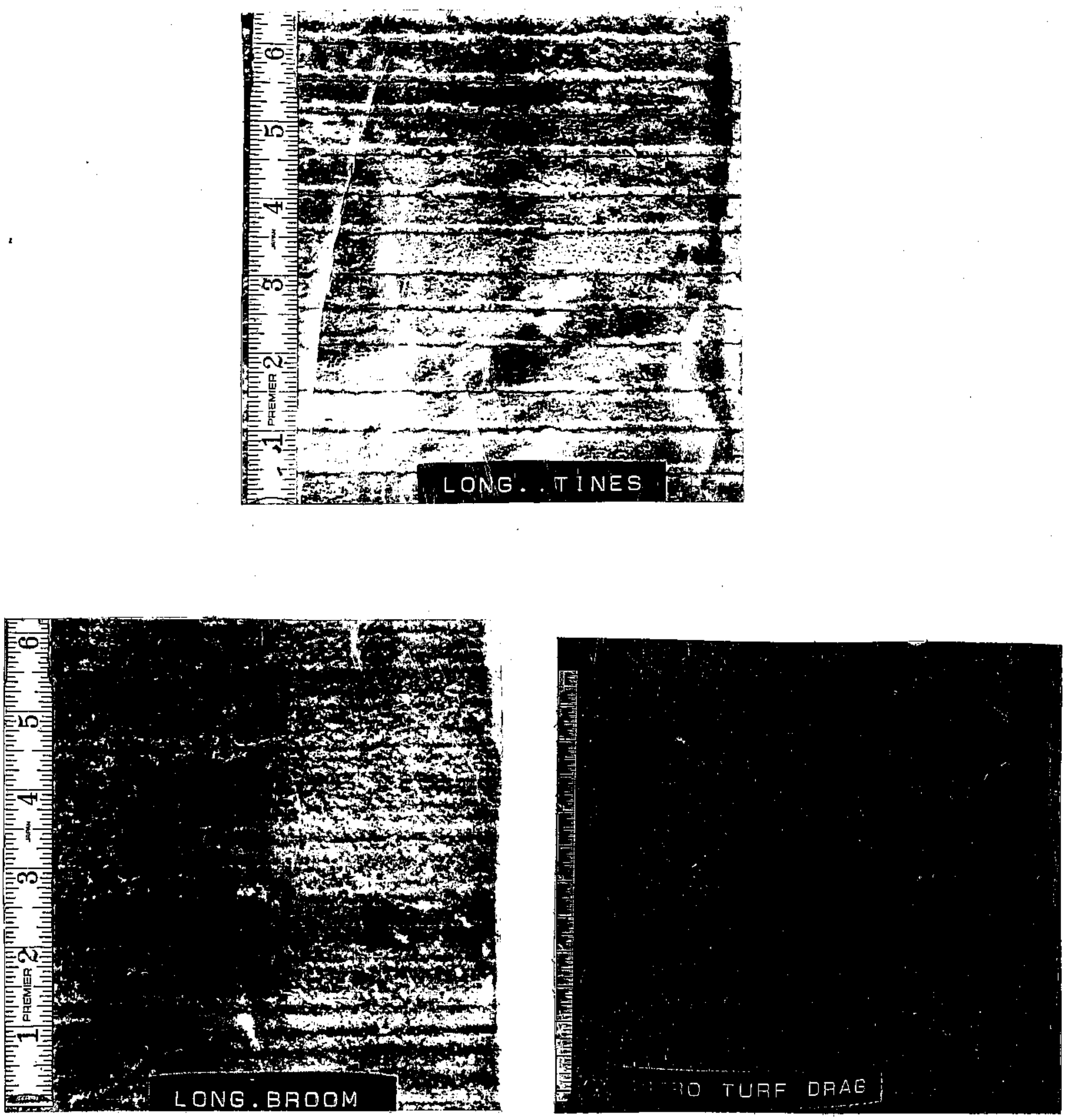


Figure 6. Photograph of Longitudinal-Textured Surface Castings

longitudinal broom and longitudinal tine and artificial-turf drag are in Figure 6.

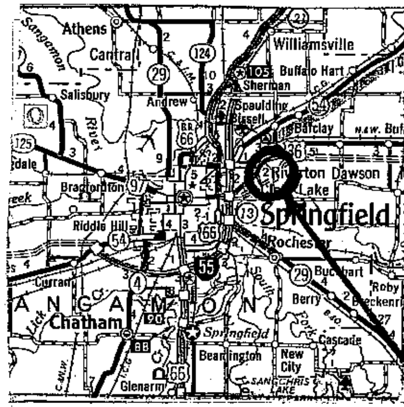
Experimental Layout

The seven textures were constructed as a part of Interstate 72 just east of Springfield, and the work plan specified that each test section was to represent one day's paving, or at least 2,500 lineal feet.

When paving began August 10, 1976, the contractor started westbound at the Sangamon River in the eastbound roadway with the transverse broom. Then, he returned eastbound in the westbound roadway, and looped back westbound, finishing with the artificial-turf drag on August 24, 1976. A layout of the test sections, as constructed, is in Figure 7. As can be seen in the figure, the longitudinal-broom and the transverse-roller textures did not meet the length criteria set forth in the work plan. Weather, an extremely tight work schedule, time and effort required to change different texturing devices, and difficulty in applying the transverse-roller texture contributed to the shorter-than-planned lengths.

Testing Program

To evaluate each texture, friction, smoothness, texture-depth, and noise, measurements were taken periodically during the 36-month study. The work plan called for a full set of measurements to be made before the pavement was opened to traffic as well as 18 months and 36 months after it was opened to traffic. Friction tests, however, were scheduled more frequently: in the spring, fall, and summer. The month and year tests actually were conducted are listed in Table 1.



General Site Location

Longitudinal Tines (7185 L.F.)	Long. Broom (1552LF)	Sang. River Bridge	Art. Turf & Tines (2465 L.F.)	Westbound

Sta. 104+37 Sta. 227+80

Eastbound	Transverse Tines (5163 L.F.)	Transverse Broom (2540 L.F.)	Sang. R. Bridge & Appr.	Artificial Turf (3393 L.F.)	Tr. Roller (1161LF)

Sta. 114+22 Sta. 248+59

Note: 1 lineal foot (L.F.) = 0.305 meters

Figure 7. Layout of Experimental Textures

TABLE 1. SCHEDULE OF TEST DATES

		Friction		Noise			Texture	
Route	Date	Tread	Smooth	Inside	Outside	RI	Sand Patch	Putty Impression
I-72	10-76	X		X	X	X	X	X
	7-77	X						
	10-77	X						
	4-78	X	X					
	5-78			X		X	X	X
	7-78				X			
	10-78	X	X					
	7-79	X	X					
	10-79	X	X				X	
	11-79			X				
	5-80					X		
I-55	6-78	X					X	
	7-79	X	X					
	10-79	X	X					
	11-79						X	

Friction tests at 30 mph, 40 mph, and 50 mph were made in accordance with ASTM E 274. They were taken in both the traffic and the passing lane, except for the initial tests, which were limited to only the traffic lane.

Smoothness measurements were recorded by a BPR-type Roadometer operating at 20 mph. Each wheelpath of both lanes was run and averaged. The results are reported as a Roughness Index (RI) in inches/mile for each test section.

Texture-depth measurements were made at 10 places along the outer wheelpath in the outer traffic lane, using both the sand-patch and the silicone-putty techniques. The mean test results permitted an evaluation of macrotexture among sites as well as monitoring changes within a site.

Noise-level measurements were made both inside and outside the vehicle to ascertain the degree of impact that texture had on noise generated between the tire and the pavement. Tests were made at 55 mph with a passenger car, both under power and coasting (engine off, in neutral).

Two B & K Sound-Level Meters, Model 2205, were used to determine the noise levels inside the vehicle beside the driver's right ear and outside the vehicle 50 feet from the centerline of the traffic lane. Measurements were taken on the "A" scale using the slow mode. The "A" scale is filtered such that the response of the meter most nearly matches the nonlinear characteristics of the human ear.

The outside measurements were made with meters located midway along each test section. When the ambient noise level was less than 10 dBA below vehicle noise, tests were aborted and were not included in the data because the noise at this level added to vehicle noise would result in an insignificant change in the total noise level.

Work Plan Revisions

During the course of the study, the work plan was revised several times because planned measurements were not achieving objectives of the study.

First, friction testing was expanded by adding ASTM E 524 smooth-tire measurements, beginning with the 18-month test series, because the ASTM E 501 treaded tire lacked sensitivity to surface macrotexture. The smooth tire is very sensitive to both microtexture and macrotexture whereas treaded tire (ASTM E 501) with its excellent drainage capacity lacks sensitivity to surface macrotexture.

Second, the noise-test program, after the 18-month tests, was altered when the study investigator determined that measurements made outside the vehicle were invalid because test-section boundaries as related to topography (cuts and fills) prevented proper orientation of noise-level meters. Consequently, the 36-month test series involved noise-level measurements only inside the vehicle under power and coasting (engine off, in neutral).

Third, the putty-impression test, even though it correlated well with the sand-patch method but at a higher level, was discontinued after the 18-month tests because test operators were not always able to seat the metal plate, used to flatten the ball of putty, solidly on the surface.

Last, a second test section of transverse-tined pavement on Interstate 55 between Gardner and Dwight was added to the study. This change resulted from a March 8, 1978 FHWA request to monitor a tined texture exposed to heavier traffic volumes.

Traffic Data

The seven textures, incorporated into Interstate 72, lie between two interchanges. Each vehicle that enters this section of roadway must travel the entire length of the test facility. Since eastbound and westbound traffic are nearly equal, each test section is assumed to have been exposed to the same traffic.

Average daily traffic (ADT) for total traffic, for total commercial traffic, and for total tractor-truck semitrailer traffic, as prepared by the Office of Planning and Programming, was used to calculate the cumulative axle passes that correspond to each set of friction tests.

The average daily traffic for both I-72 and I-55 test sections is tabulated below:

Type Vehicles	Average Daily Traffic I-72	I-55
Total Traffic	7,000	12,200
Passenger Cars	5,000	9,200
Single-Unit Trucks	1,000	650
Multi-Unit Trucks	1,000	2,350

Over the 36-month study period, I-72 received almost 8 million axle applications as compared to nearly 6 million applications on I-55, which were accumulated at a faster rate in 16 months.

TEXTURE-DEPTH RESULTS

Macrotexture, especially effective at operating speeds above 35 mph, provides escape channels for water trapped between the pavement and a tire, allowing the tire to maintain its grip on the roadway. Although the literature describes over 28 measuring methods, the sand patch, a frequently used technique, and the putty impression were the ones selected for use in this study. This section draws a comparison between the two methods, provides a quantitative measure of texture among the seven finishes, and discusses the loss in texture depth caused by 36 months of traffic wear.

A comparison between the sand-patch and the putty-impression texture-depth measurements can be seen in Figure 8. The putty-impression method correlates (r = 0.92) reasonably well with the sand-patch method, but its value at the "y" intercept stands approximately 30 mils above the corresponding sand-patch value. As indicated in the figure, the putty-impression method had a standard error of estimate of 3.5 mils, which is attributed partly to a different operator each test date.

A tabulation of individual texture depths by test method and test date can be seen in Table 2. Both test methods indicate that tined textures provide more macrotexture than either broomed or artificial-turf textures; however, some anomalies can be seen in the May 1978 rankings between the two methods. The putty-impression method, for example, ranks the artificial-turf and transverse broom above the transverse roller. Furthermore, test operators believed that the putty-impression method was subject to some error because they were not always able to seat the metal plate, used to flatten the ball of putty, solidly on the pavement surface. This fact may partly explain the anomalies in the rankings. The putty-impression method also lacked sensitivity, because the range of values for it was narrower than that for the sand-patch method. For these

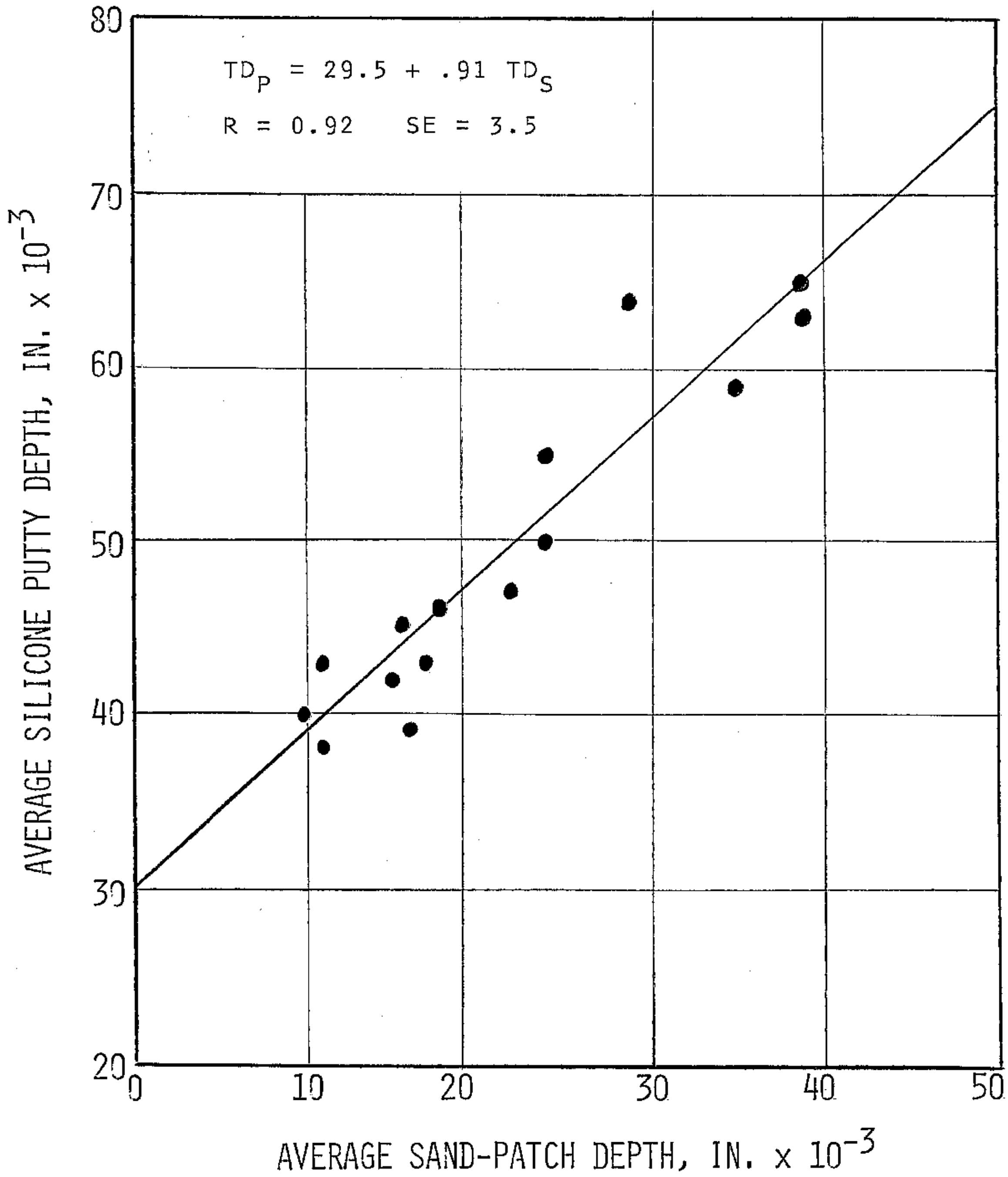


Figure 8. Sand-patch versus putty-impression texture measurements

TABLE 2. SUMMARY OF TEXTURE-DEPTH MEASUREMENTS

Texture	Average Depth in Mils				
	Sand Patch			Putty Impression	
	Oct 76*	May 78	Oct 79	Oct 76	May 78
			Interstate 72		
Artificial Turf & Trans. Tine	39	35	37	63	59
Transverse Tine	29	24	28	64	55
Longitudinal Tine	22	17	20	47	43
Transverse Roller	18	16	20	46	39
Artificial Turf (control)	24	10	13	50	40
Longitudinal Broom	15	11	13	42	38
Transverse Broom	16	11	11	45	43

Texture	Average Depth in Mils	
	Sand Patch	
	June 78*	Nov 79
	Interstate 55	
Transverse Tine	54	26

*Initial tests before traffic

Note: 1.0 in. = 2.54 cm

reasons, the putty-impression method was excluded from the final test series.

As previously indicated, the tined finishes, as expected, provided deeper macrotexture than the broomed and the dragged finishes. Initially, and after almost 8 million cumulative axle passes, the artificial-turf/transverse-tine combination still provides the best macrotexture, 10 to 27 mils deeper than any of the others. This finding reinforces the Division's March 1976 decision to implement this texture as the final finish for PCC pavement before starting this study.

A closer examination of Table 2 reveals that the rapid loss that occurred between the initial and 18-month measurements has been checked since the 36-month values were 2 to 4 mils higher than corresponding 18-month values. The average loss amounted to 4 mils. This change represents a 0 to 18 percent reduction for the deep-grooved textures as compared to 20 to 40 percent reduction for the broomed and dragged textures.

Whether or not the texture loss will continue, but at a slower rate, is unknown because the test-measurement precision masks any evidence of a trend. Moreover, the May 1978 and October 1979 test results suggest that a 2- to 4-mil variation probably existed between test operators.

FRICTION-TEST RESULTS

One important aspect of PCC pavement texturing deals with its friction characteristics. The work plan originally called for tests with only the ASTM E 501 treaded tire but, after the first year, test results indicated that the treaded tire was insensitive to the macrotexture of the various test sections. This led to adding measurements with the ASTM E 524 smooth-tread tire for the remainder of the study. The smooth-tire test results, as expected, did delineate the various degrees of macrotexture among the test sections.

This section compares the change in friction relative to traffic wear and looks at how the various textures affect the friction number-speed gradient (FNG).

Wear Curves

The change in friction number (40 mph) with respect to traffic wear can be examined in Figure 9 for the treaded tire (ASTM E 501) and in Figure 10 for the smooth tire (ASTM E 524).

Looking first at the treaded-tire results (Figure 9), initial friction numbers varied widely from a high of 71 for the artificial-turf/transverse-tine combination to a low of 32 for the transverse roller. The low transverse-roller value is attributed to a steel-trowel-like finish created by the steel roller used to groove this section. As soon as traffic began wearing the surface, sand particles, however, were exposed, increasing friction comparable to that of the other textures. Conversely, the friction number of the other textures, especially the transverse-tined ones, dropped rapidly to a lower level. By the time the 18-month tests were made, the spread had narrowed to 7 from 39 friction numbers, with all test sections stabilizing in the 50's.

Although the transverse-tined section on Interstate 55 initially had the highest friction number (75), its level when the study ended dropped to 49, which equals the transverse broom and the artificial-turf drag values but stands below the transverse-tine value of 53 for Interstate 72. Since the daily axle applications on Interstate 55 almost double those of

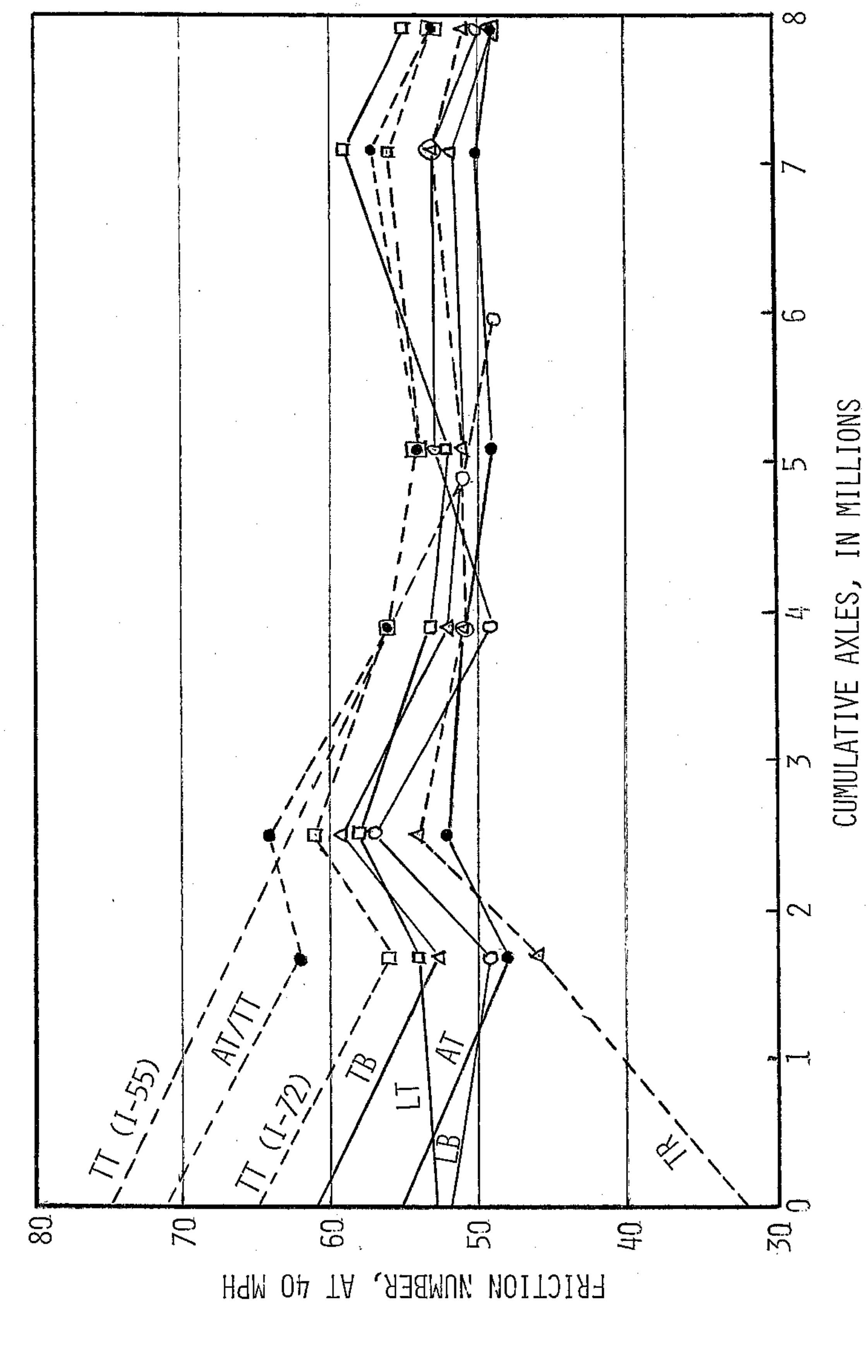


Figure 9. A comparison of treaded-tire wear curves by textures

Interstate 72, a surface carrying a higher average daily traffic can be expected to have a slightly lower friction number than a similar surface carrying a lower ADT.

Besides illustrating the wear aspects of the various PCC pavement textures, this graph also points out that the ASTM E 501 treaded tire lacks sensitivity to surface macrotexture. Even though the July and October 1979 measurements tend to rank coarse above fine textures, we do not know whether this tendency will continue.

On the other hand, wear curves (Figure 10), based on the ASTM E 524 smooth tire during the last 18 months of the study, had a wide range of friction numbers, from the low 50's to the low 20's, which is contrary to the narrow spread found with the treaded tire. The tined finishes were in the 40 to 55 range; the broom and the drag finishes lie close together in the 20 to 27 range, while the transverse-roller finish was between the other two groups. These data clearly indicate that the ASTM E 524 smooth-tread tire is sensitive to both surface macrotexture and microtexture and, as macrotexture increases, smooth-tire friction numbers approach, or even sometimes surpass, treaded-tire values.

When treaded-tire and smooth-tire friction numbers are compared to each other, as in Figure 11, the treaded-tire values fall within a very narrow range as opposed to a much wider range for the smooth-tire values. The data points, which represent both traffic and passing lanes, can be divided into three distinct groups: top, middle, and bottom. The top group, lying close to the line of equality, contains the transverse-tined finishes and the middle group, which contains the longitudinal-tine and the transverse-roller textures, subjectively can be considered medium textures.

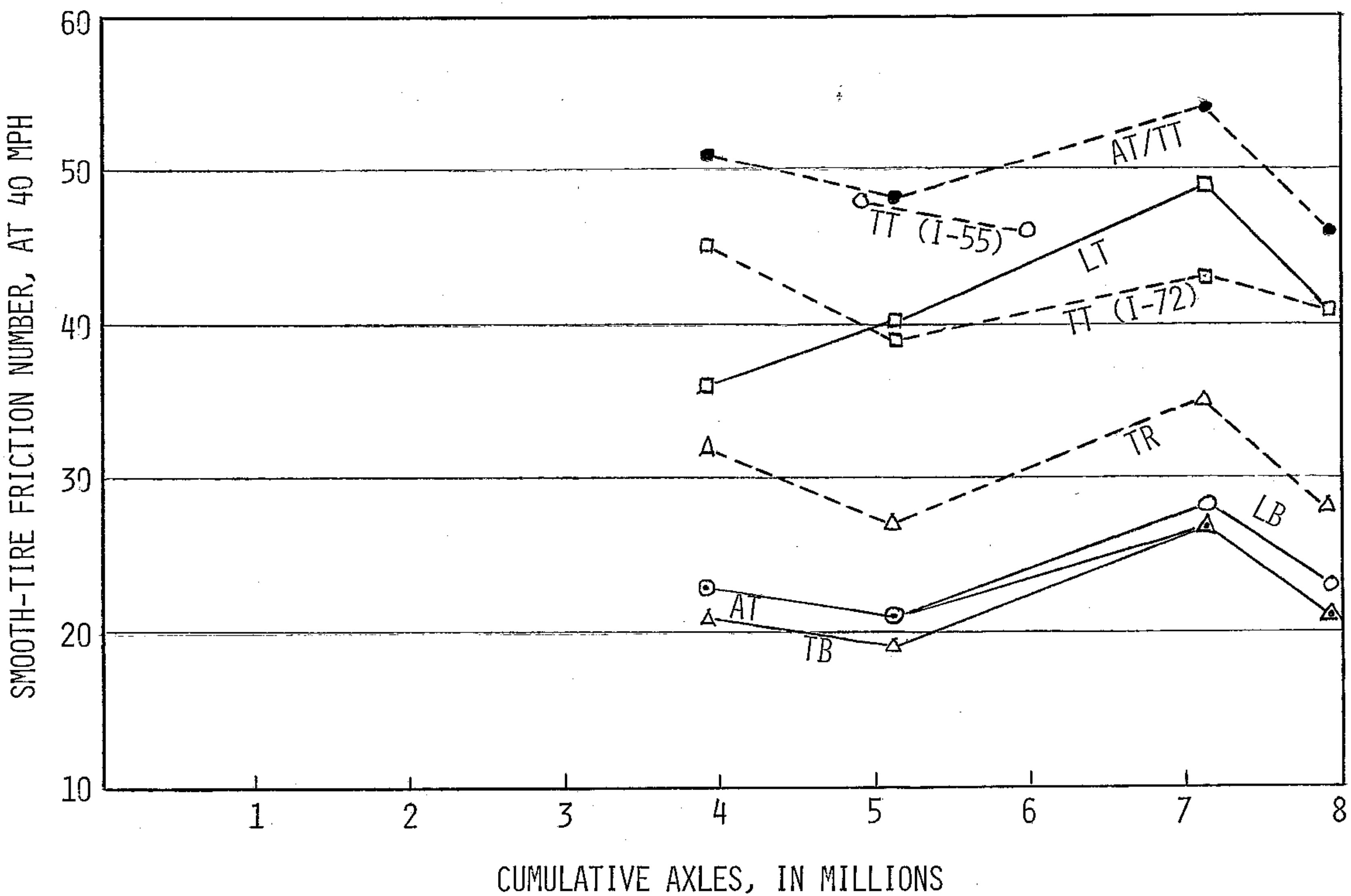


Figure 10. A comparison of smooth-tire wear curves by textures

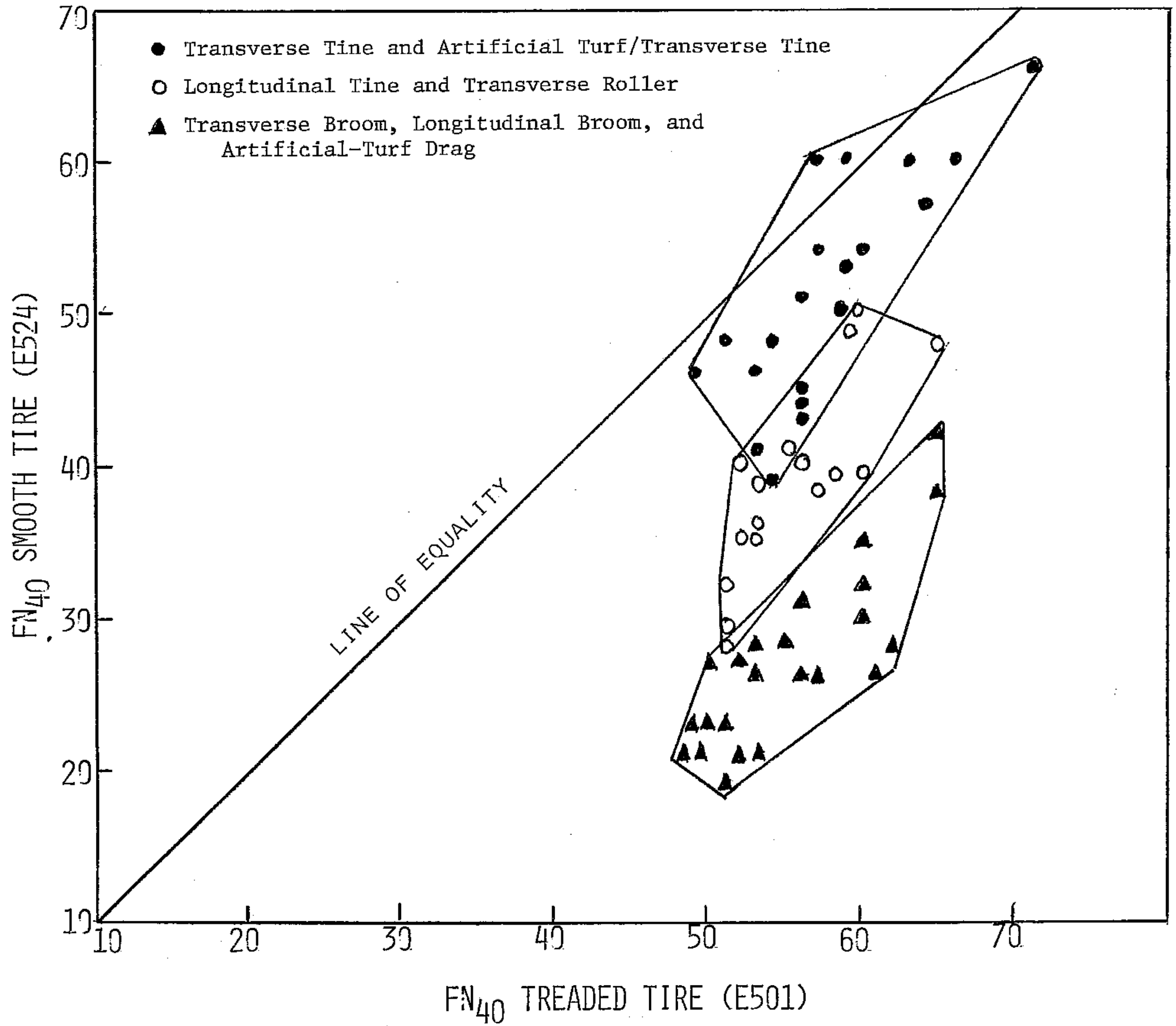


Figure 11. Smooth-tire versus treaded-tire friction numbers

The bottom group, on the other hand, containing the broom and the drag finishes, are considered as fine textures.

The results of friction tests made during the last half of the study reinforce Henry's (2) findings that the ASTM E 501 treaded tire is a poor discriminator of the drainage capability produced by pavement macrotexture.

When water is applied at the rate specified by the ASTM E 274 test method, the treaded tire with its deep grooves, according to Henry, provides ample drainage without taking into account any drainage provided by the macrotexture of the pavement.

On the other hand, results obtained from the ASTM E 524 smooth-tread tire, which more than doubled the treaded-tire range, clearly ranks the various finishes according to their drainage capability.

Friction Number-Speed Gradients

The skid resistance of a pavement surface varies with vehicles speed. Although this relationship is nonlinear for most pavement surfaces, it usually is approximated as a straight line. The standard gradient is defined as the slope of this line at 40 mph and is determined as:

$$FNG = \frac{FN_{30} - FN_{50}}{20}$$

where FNG = friction number-speed gradient between 30 and 50 mph

FN_{30} = friction number at 30 mph

FN_{50} = friction number at 50 mph

20 = the difference in velocity between 30 and 50 mph

Friction number-speed gradients were monitored throughout the study period, and a comparison of them by textures can be seen in Figure 12. The figure draws a comparison not only between initial and final treaded-tire

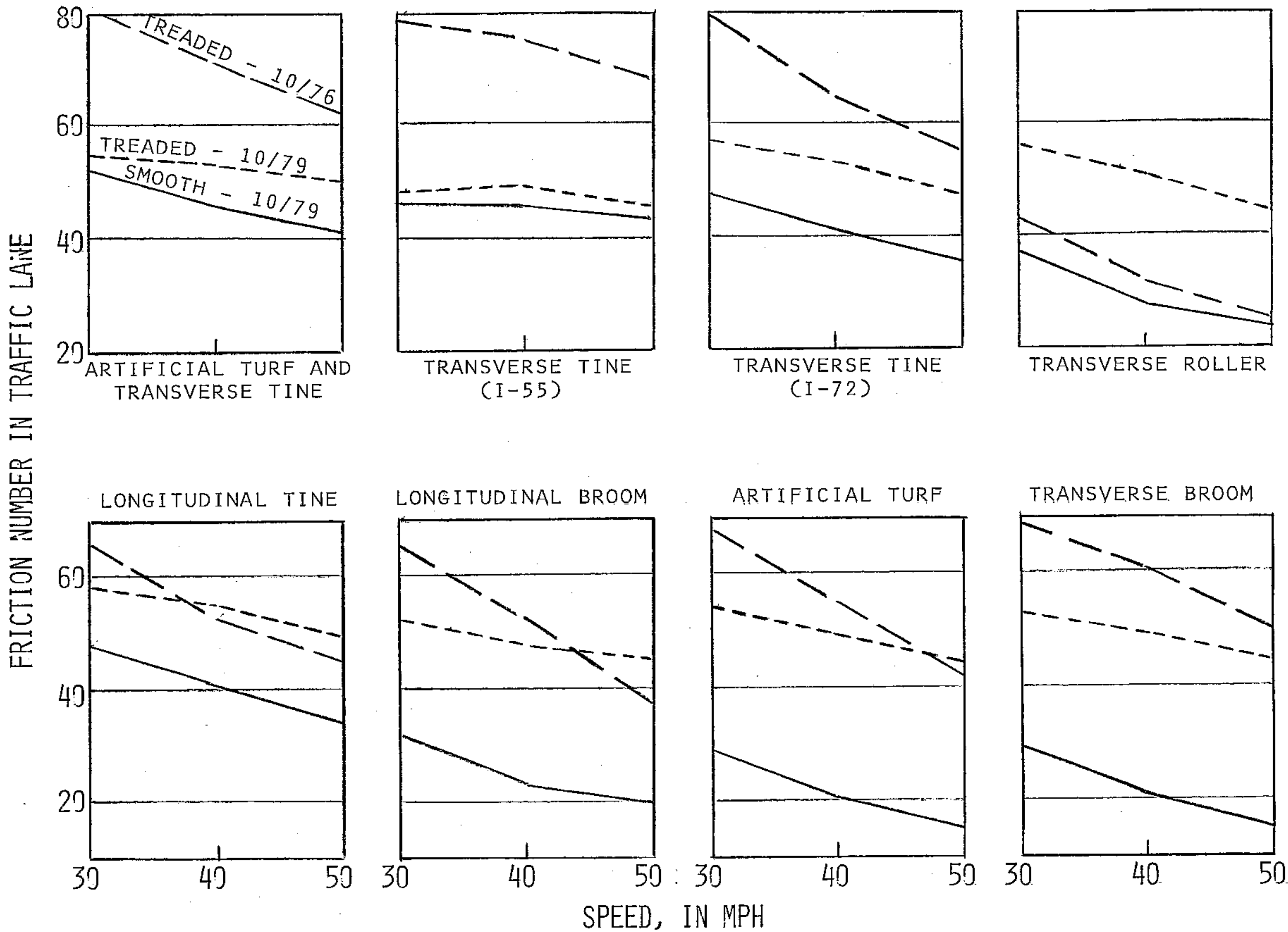


Figure 12. A comparison of friction number-speed gradients by textures

gradients but also between final smooth-tire and final treaded-tire gradients.

Initially, the gradients were high (0.8 to 1.4), with no apparent trend involving texture; however, the level of the gradients began to drop as traffic wore the surface. At the close of the study, the gradient values ranged from 0.6, for the transverse-roller texture, to 0.1 for the transverse-tine texture on Interstate 55, with no apparent trend involving texture emerging.

Smooth-tire gradients, at the end of the study, were, for all practical purposes, the same (0.6) among the I-72 textures, but they were generally steeper than their corresponding treaded-tire gradients. These results suggest that neither treaded-tire nor smooth-tire gradients have any strong relation with the macrotexture in PCC pavements. Although trends sometimes seem apparent between gradients and surface texture, they were not evident during this study.

The gradients, however, did tend to be influenced by changes in microtexture. For example, high initial friction numbers produced steep gradients, and as the level of friction dropped with traffic wear, the gradients flattened. This tendency also has been observed in bituminous surfaces as well as by other investigators.

TEXTURE-DEPTH INDICATORS

Friction mesurements made during the course of this study afforded an opportunity to evaluate surrogate texture-depth indicators. Sand-patch texture-depth measurements were compared to the following seven indicators:

(1) Treaded-tire friction number-speed gradient (FN_tG)

(2) Smooth-tire friction number-speed gradient (FN_sG)

(3) Percent treaded-tire friction number-speed gradient (PFN_tG)

(4) Percent smooth-tire friction number-speed gradient (PFN_sG)

(5) Smooth-tire friction number (FN_s

(6) Treaded-tire less smooth-tire friction number (FN_{t-s})

(7) Macrotexture Index: which is defined as the ratio of the sum to the difference of a treaded-tire and a smooth-tire friction number plus 1, which eliminates negative values $\left[\frac{FN_{t-s}}{FN_{t+s}} + 1\right]$

Gradients

The first comparisons involved sand-patch texture depth and the friction number-speed gradients and the percent friction number-speed gradients, which are shown in Figure 13. Initially, no correlation ($r = 0.14$) existed between texture depth and the FN_tG. At 18 months, however, a strong correlation ($r = 0.98$) emerged, but 18 months later, it weakened ($r = 0.46$), suggesting that the high r value at 18 months probably occurred by chance. Moreover, the level of the gradient dropped on each succeeding test date, indicating its sensitivity to changes in microtexture. In fact, the two smooth-tire gradients also had relatively weak correlations. For a correlation obtained from a seven-point sample to be significant at the 95 percent level, an r value above 0.75 is required. These findings support those of other investigators which say friction number-speed gradients do not correlate well with texture depth.

Percent Gradients

Recognizing that the friction number-speed gradient is sensitive to changes in microtexture, several researchers have found that the percent

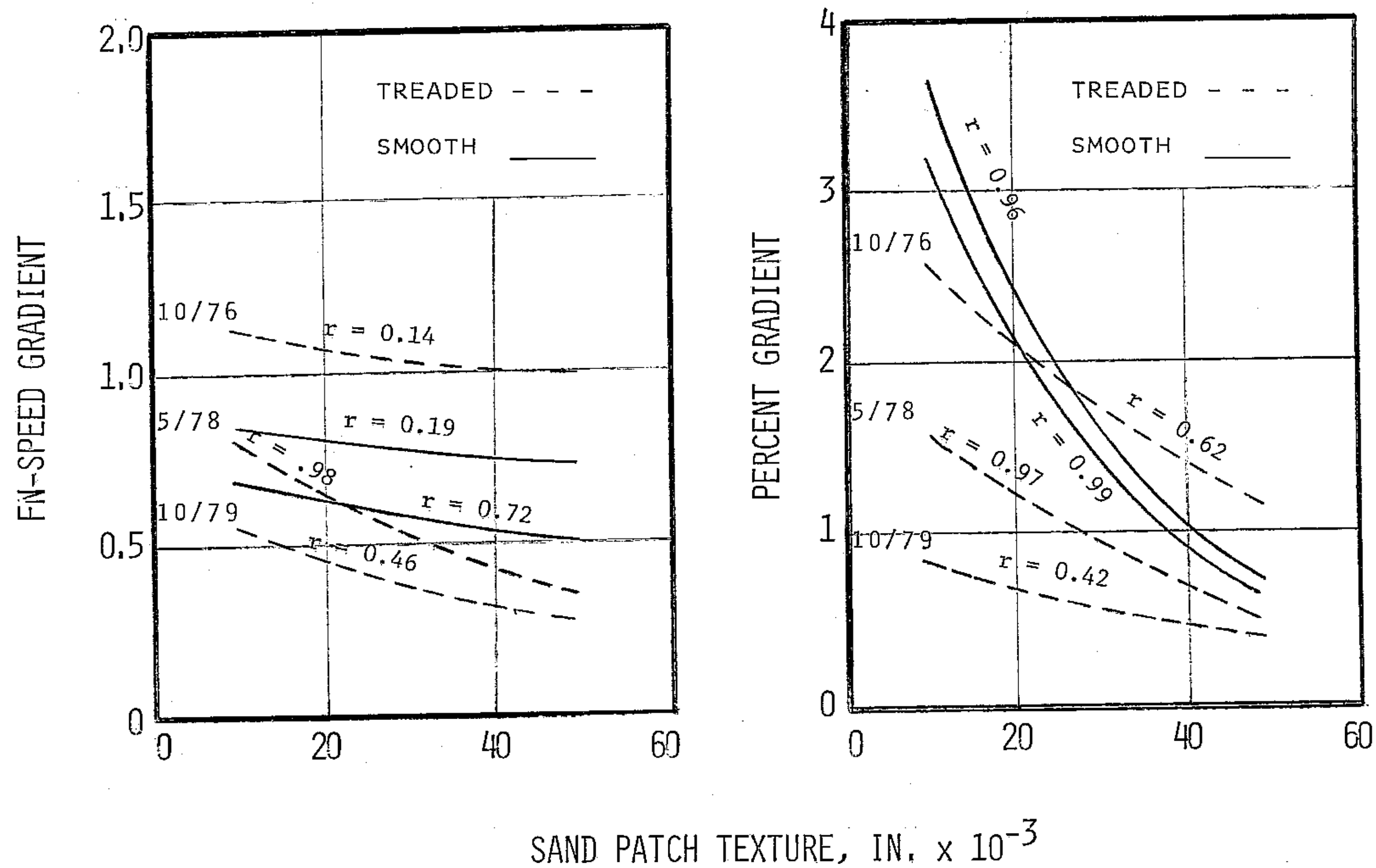


Figure 13. Friction number and percent friction number-speed gradients versus texture depth

friction number-speed gradient (PFNG) is more highly correlated with macrotexture than friction number-speed gradient (3). The PFNG, which is also known as the normalized friction number gradient, is defined as:

$$PFN = \left(\frac{FNG}{FN_{40}}\right) 100$$

The percent friction number-speed gradient, as can be seen in Figure 13, did improve the May 1976 treaded-tire correlation coefficient, from -0.14 to -0.62, but the change for May 1978 and for October 1979 was insignificant.

On the other hand, the percent smooth-tire friction number-speed gradient for the May 1978 and October 1979 tests both produced high correlation values, -0.96 and -0.99, respectively. These curves imply that PFN_sG depends on texture depth and could serve as a predictor of texture depth. Consequently, they were combined, and the resulting power regression curve (r = -.96, SE = 2.7 mils) is presented in Figure 14.

One disadvantage of using PFN_sG as a predictor of texture depth is that smooth-tire measurements are needed at three test speeds (30 mph, 40 mph, and 50 mph). In addition to the smooth-tire tests, a treaded-tire test at 40 mph also should be taken to give a complete description of the surface's friction characteristics. This involves a minimum of at least four test runs at a site, which not only is costly but also is time-consuming.

Smooth Tire FN

Smooth-tire FN also correlates well to texture depth. The resulting exponential curve (Figure 15), obtained from the May 1978 and October 1979 data, has a correlation coefficient of -0.93 and a standard error of

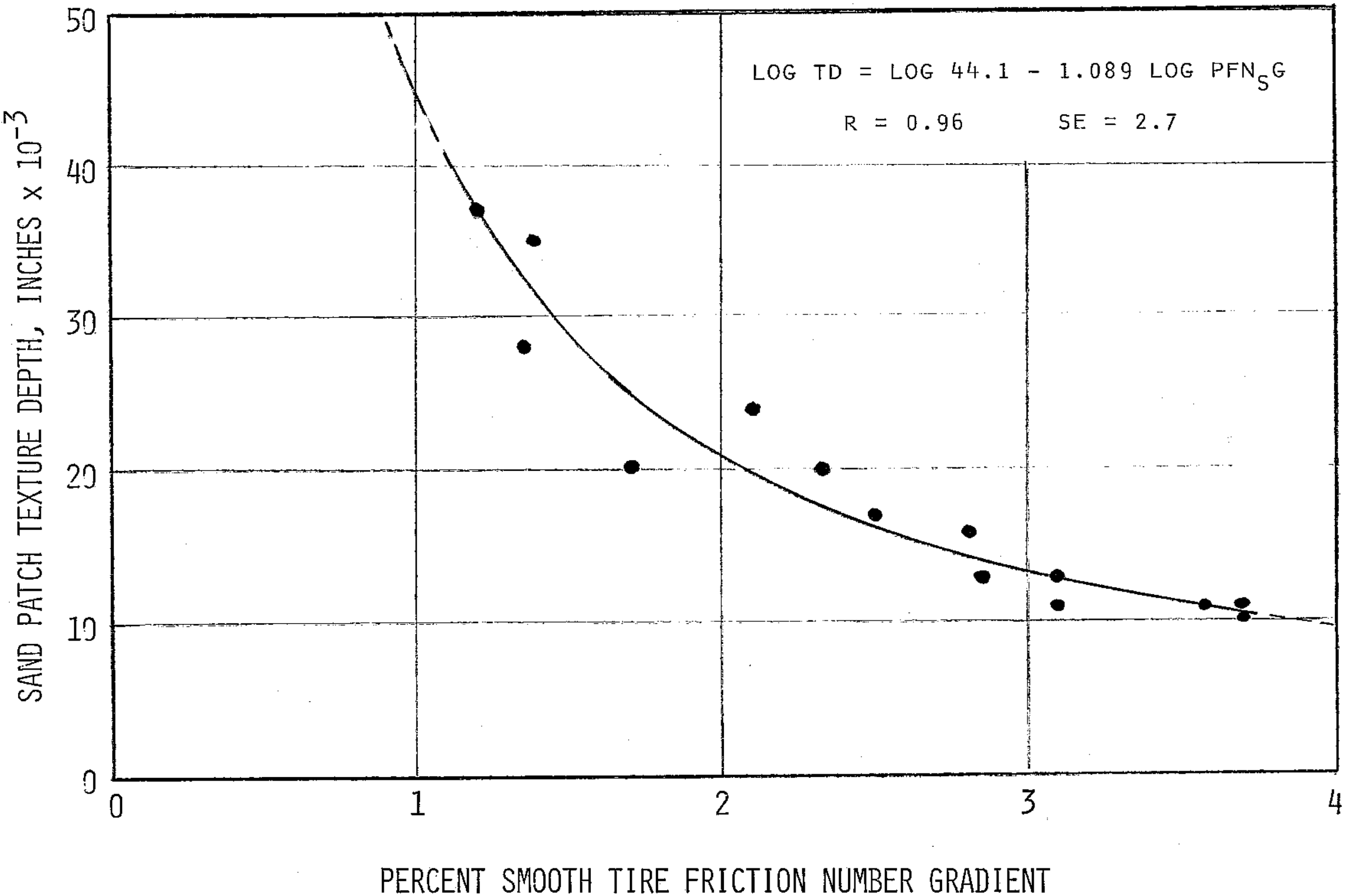


Figure 14. Texture depth versus percent smooth-tire friction number-speed gradients

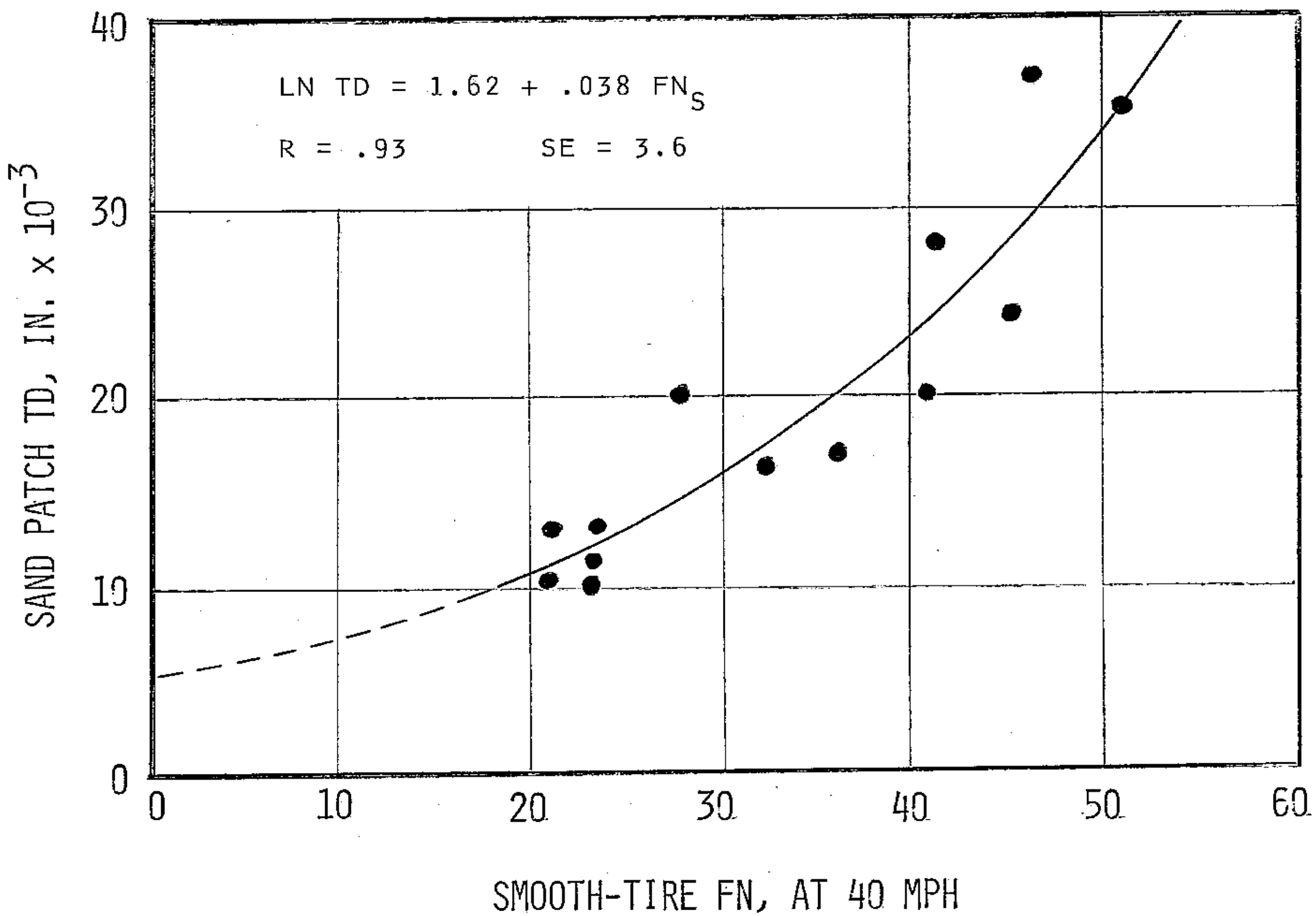


Figure 15. Texture depth versus smooth-tire friction number

estimate of 3.6 mils, which is slightly more but still comparable to the PFN_sG curve.

The smooth-tire FN indicator has an advantage over the PFN_sG indicator in that testing is done at only one instead of three test speeds. This obviously is an improvement in test efficiency, but this advantage holds true for only a narrow range (say less than 10) of FN_t values, like those in this study.

The smooth-tire FN loses its credibility as a texture indicator when it is applied to a whole universe of surfaces. For example, consider two open-graded friction courses having the same macrotexture but one contains dolomite and the other air-cooled slag aggregate. The dolomite surface has an FN_s of 35 as compared with an FN_s of 51 for slag. These values imply that the slag surface contains more macrotexture than the dolomite surface when they both actually have the same macrotexture. From the viewpoint of test efficiency, a smooth-tire friction test at one speed would be ideal, but its use as a macrotexture indicator must be ruled out because it cannot serve as a universal indicator.

Treaded-Tire minus Smooth-Tire FN

Another indicator involves the difference between treaded-tire and smooth-tire friction numbers versus texture depth. The resulting exponential regression curve (Figure 16) also indicates a strong correlation coefficient (-0.95) and a standard error of estimate of 3.6 mils, which is similar to that for the PFN_sG and the FN_s curves. This indicator not only is a good predictor of macrotexture but it also has the same testing efficiency as the smooth-tire indicator. It requires one run with a treaded tire and another run with a smooth tire. In fact, both runs

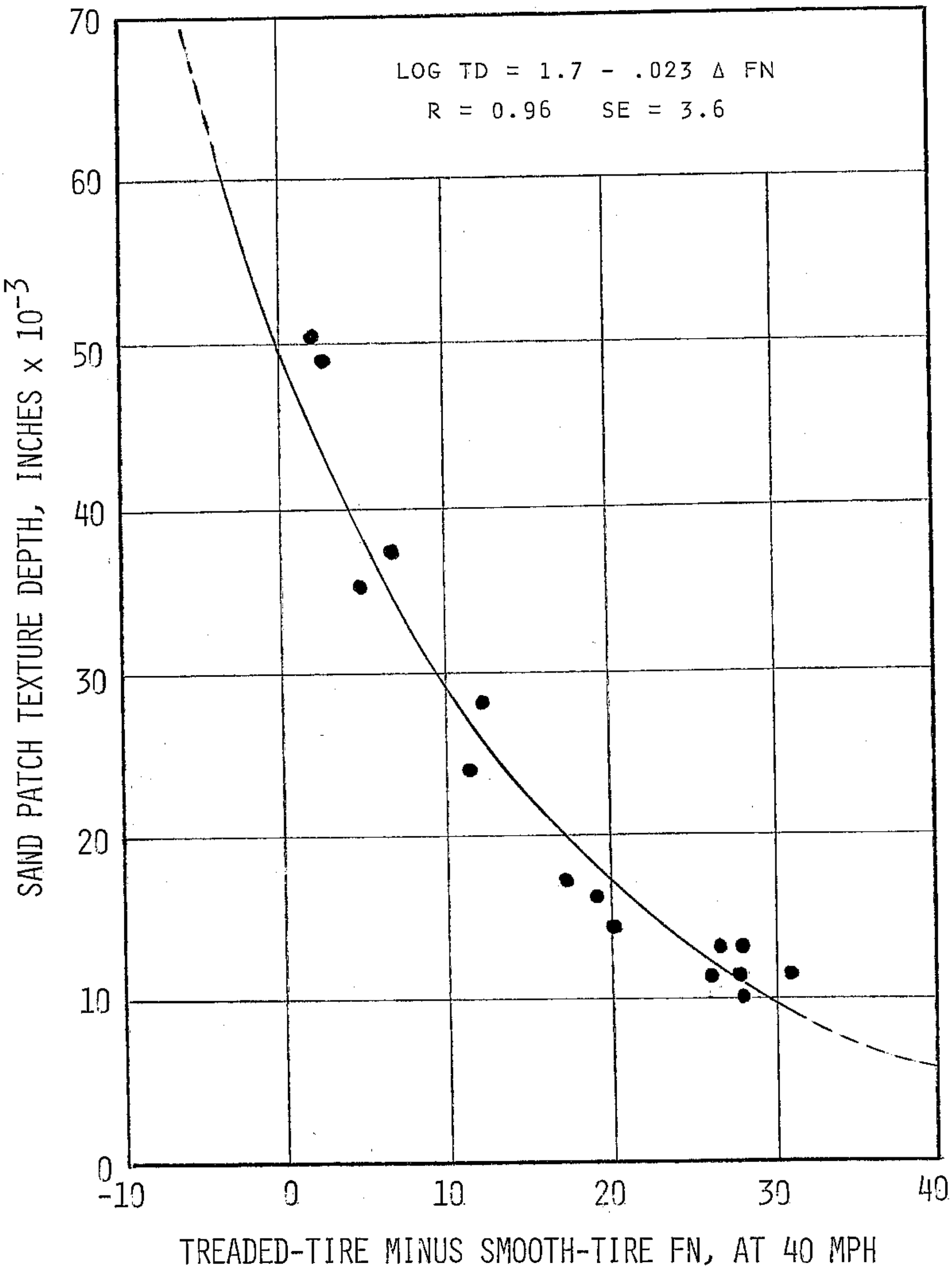


Figure 16. Texture depth versus treaded-tire minus smooth-tire friction number

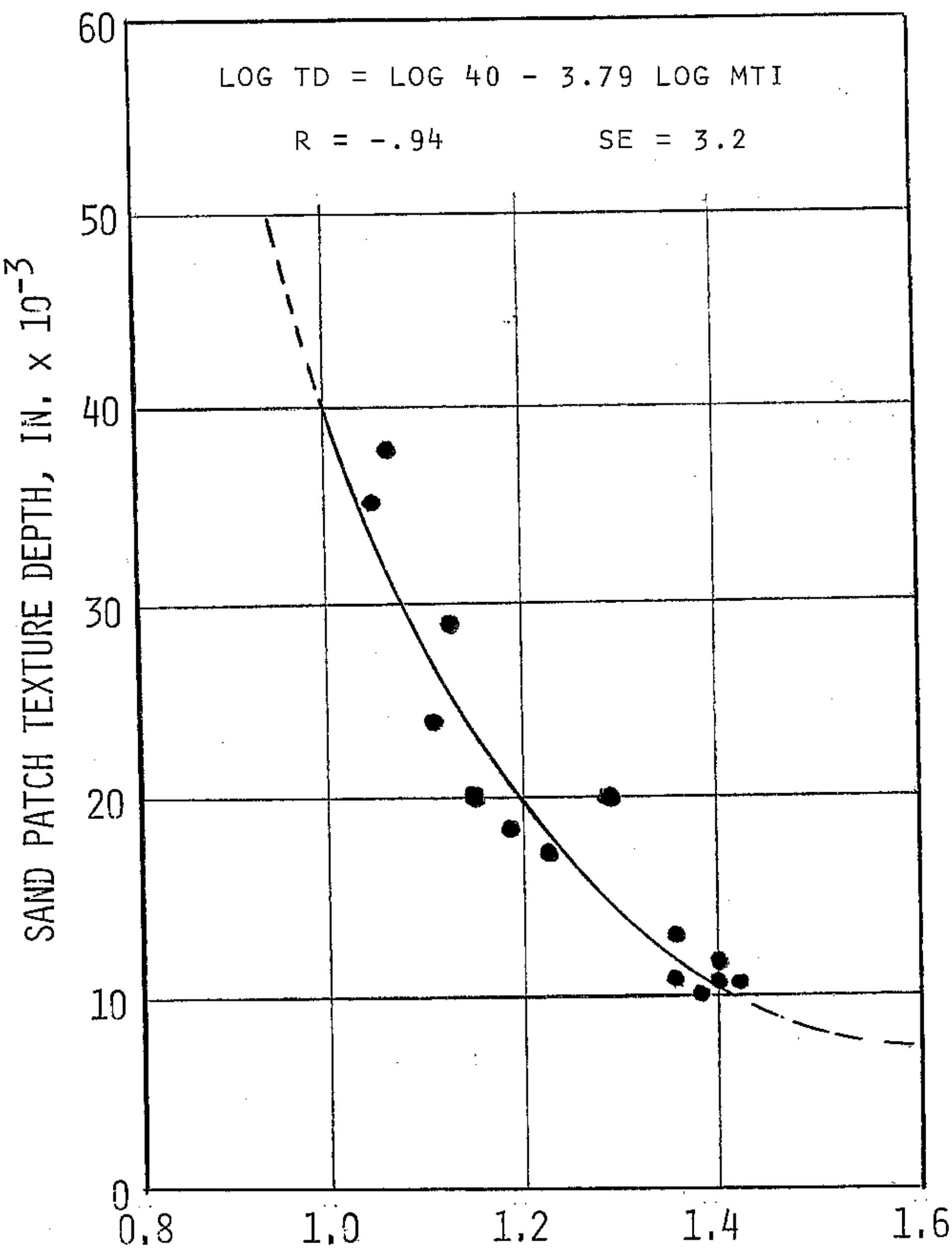
could be combined into one run by alternating right (smooth tire) and left (treaded tire) wheel tests along a section of highway. The treaded-tire friction number gives an indication of microtexture while the treaded-tire minus the smooth-tire friction gives an indication of macrotexture.

Initially, this scheme was believed to be as good as the PFN_sG indicator, and better than the FN_s indicator, but it too can have anomalies. They occur when test surfaces have low friction numbers, say below 30.

For example, one dense-graded bituminous surface carrying high traffic volumes had an FN_t and an FN_s of 30 and 17, respectively, a difference of 13 friction numbers between the two tires. This difference, according to the FN_{t-s} curve (Figure 16), indicates that the surface should have a texture depth of 25 mils when actually the measured value was 9 mils. This situation can occur any time a surface has low friction, causing the difference between the two tires to be smaller than expected, inferring a deeper-than-actual texture depth.

Macrotexture Index

One way of reducing anomalies in the FN_{t-s} indicator is to normalize the difference in friction between the two tires. This indicator, called the Macrotexture Index, is equal to the ratio of the difference to the sum of a treaded-tire and a smooth-tire friction number plus 1, which eliminates negative values when smooth-tire friction numbers exceed treaded-tire friction numbers on coarse-textured surfaces. The regression curve for this Index can be seen in Figure 17. The best fit is a power regression curve having a correlation coefficient equal to -0.94 and a



$$M\,T\,I = \left(\frac{FN_T - FN_S}{FN_T + FN_S} + 1\right)$$

Figure 17. Texture depth versus Macrotexture Index

standard error of estimate equal to 3 mils, which are comparable to those values for the PFN_sG, FN_s, and FN_{t-s} curves.

Of the indicators investigated, the Macrotexture Index shows the most promise of serving as a surrogate texture-depth indicator, and it can be obtained by either alternating left (treaded-tire) and right (smooth-tread tire) wheel lockups or making two test runs, one with a treaded tire and the other with a smooth tire. The choice of which method to use depends on the length of the surface to be tested and on the variability in surface texture. Although alternate tire testing in one run may increase the prediction error, it still will determine, with a high degree of certainty, whether a surface possesses a coarse, a medium, or a fine texture.

The mathematical calculations necessary to determine the Macrotexture Index can be eliminated through the use of the nomograph shown in Figure 18. For various texture depths, corresponding index values were back calculated to a treaded-tire and a smooth-tire value, establishing a family of texture-depth curves. To illustrate their use, the last friction tests on the transverse-roller texture will be used. A treaded-tire value of 51 is entered at the x axis and a smooth-tire value of 28 is entered at the y axis, and they both are projected to their point of intersection. At this point we find an estimated texture depth of 16 mils, which equals the May 1978 measured value and which is 4 mils less than the October 1979 value of 20 mils.

SMOOTHNESS TEST RESULTS

Previous experience indicated that the riding quality of a pavement, as measured by Illinois' Roadometer, is influenced not only by longitudinal and transverse undulations but also by surface texture (4). Pavement

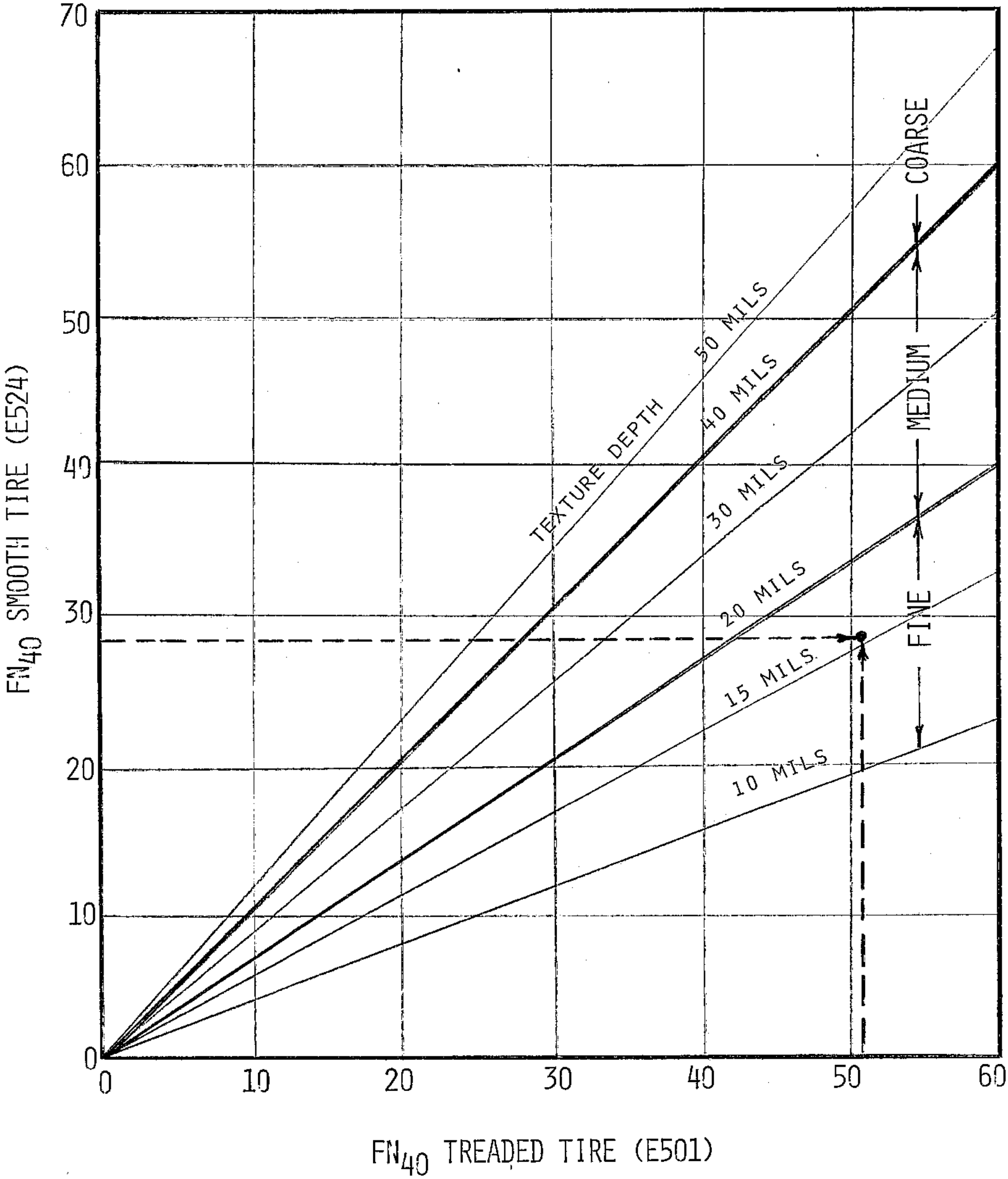


Figure 18. Texture-depth Nomograph

smoothness, like noise and texture-depth tests, also was measured three times during the study period, and the recorded output, which is called Roughness Index (RI), is reported in inches per mile.

Average RI values for the test sections before the pavement was opened to traffic ranged from a high of 91 inches/mile, for the artificial-turf/ transverse-tine combination to a low of 72 inches/mile for the longitudinal broom finish. Adjective ratings (4) of riding quality corresponding to these RI values are: "very smooth" (RI = 75 or less), "smooth" (RI = 76 to 90), and "slightly rough" (RI = 91 to 125).

Because pavement smoothness fluctuates with time, direct comparisons of RI values among test dates were impractical. To evaluate how smoothness among textures changed with time, RI values were examined relative to those for the articifical-turf (control), which was assumed constant during the three test dates. The test results evaluated in this manner can be seen in Figure 19.

Initially the transverse-grooved textures were from 10 to 12 inches per mile rougher than the artificial-turf (control) while the longitudinal-tine and the broomed textures were from 3 to 8 inches per mile smoother than the control texture. The initial results suggested a strong correlation existed between texture depth and smoothness, but after traffic began wearing the surface, evidence of a correlation disappeared. All of the textures lost roughness under traffic, but the deep transverse-grooved textures still were rougher than the longitudinal-tined and the broomed textures. When examining the direction of texturing, the evidence indicates that transverse textures add roughness over corresponding longitudinal textures.

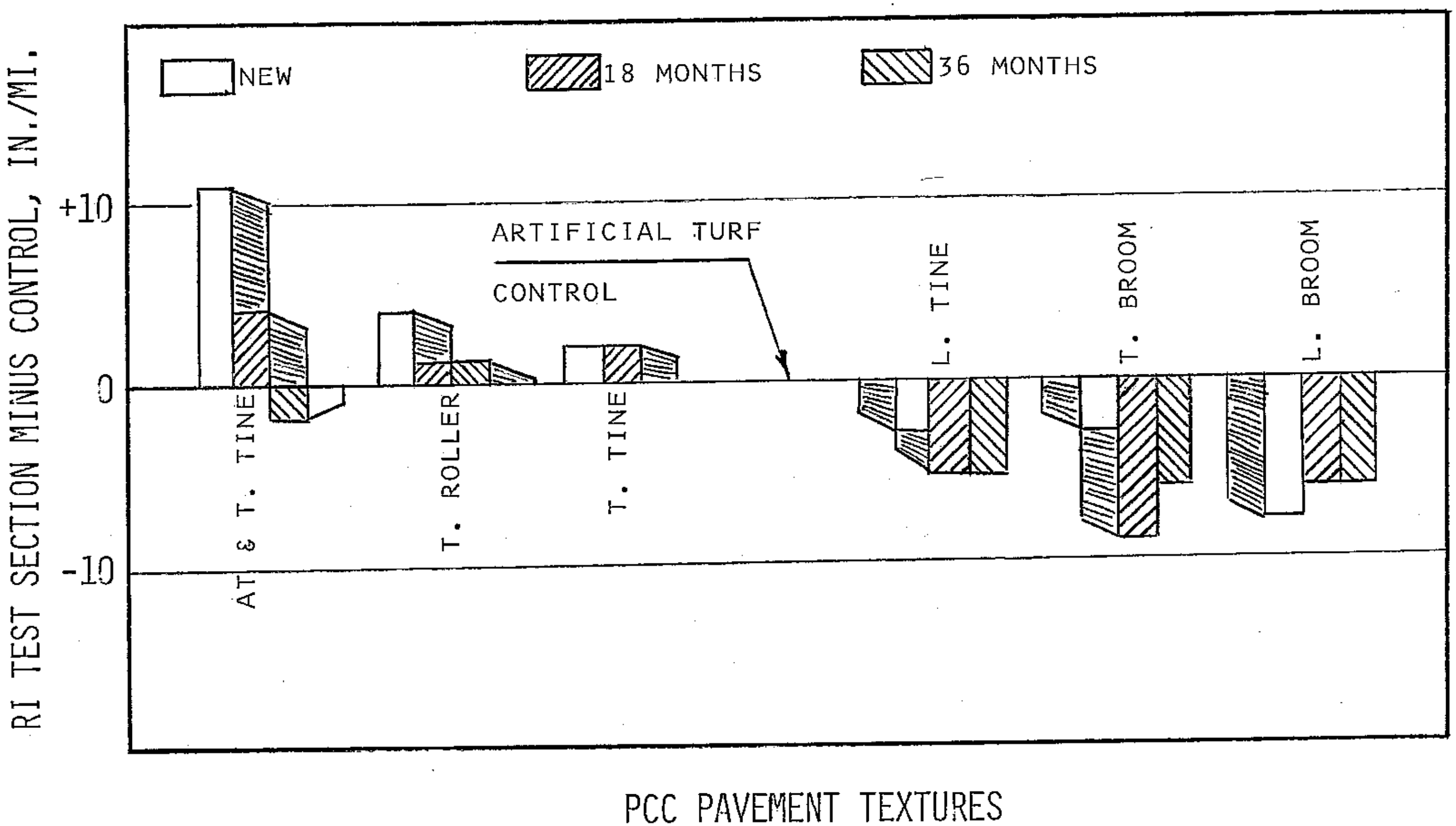


Figure 19. Change in Roughness Index relative to artificial turf

NOISE-LEVEL TEST RESULTS

Noise-level measurements, as previously mentioned, were taken three times during the study period. The first time was before the roadway was open to traffic. The second and third followed 18 months and 36 months, respectively, after this section of Interstate was opened to traffic.

Results of the initial tests can be seen in Figure 20. Those made with the engine running masked the actual noise generated between the tire and the pavement texture. They were, as expected, higher than the noise levels measured with the enginer off by up to 3 dBA.

From a subjective viewpoint, a 3 dBA change in sound is barely discernible to the ear; yet this change constitutes a doubling of sound level (6). Correspondingly, humans usually perceive a doubling of noise when a 10 dBA change occurs, but the noise level actually has increased 10 times the reference sound-level pressure. Initially, the range (0 to 3 dBA) between a powered and a coasting vehicle were, at worst, just discernible for any given texture.

The levels measured while coasting contain both a tire-pavement and a wind component. By using the same vehicle and vehicle speed for each set of tests, the wind component should remain constant, and any variation in noise level is attributed to differences in texture. Among textures, the range, both inside and outside the vehicle, was between 5 and 6 dBA, respectively, which is definitely noticeable.

Transverse-textured surfaces, according to the results, tend to be noisier than longitudinally textured surfaces, and deep-grooved finishes are noisier than broomed and dragged finishes. While conducting the tests, the transverse-roller texture sounded noisier to the test crew than any

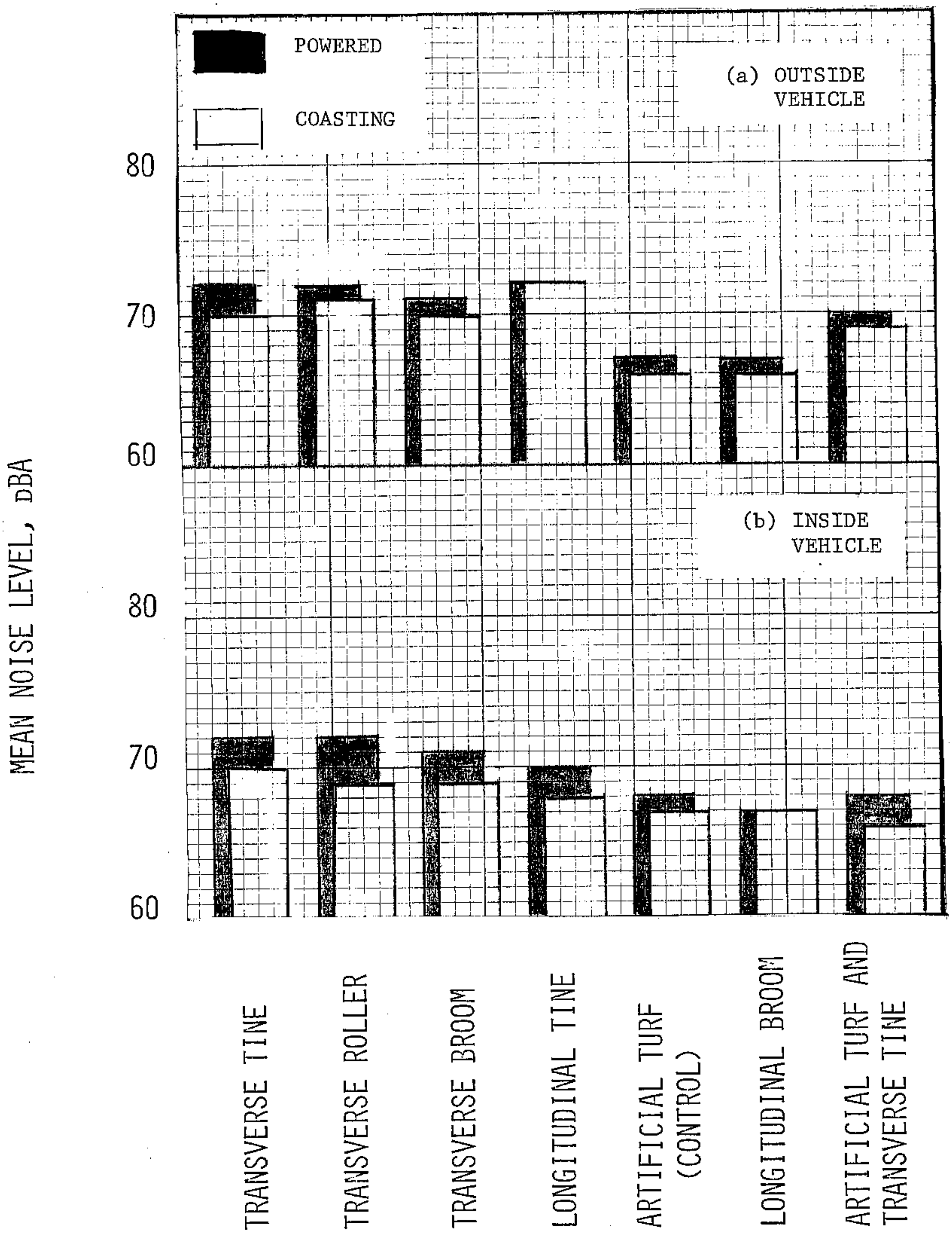


Figure 20. Comparison of initial noise level with and without vehicle power by texture

other texture. This undoubtedly was due to two facts. First, its grooves were deeper and wider than the tined grooves and, second, the grooves had a uniform 2-inch spacing, which produced a predominant narrow-band frequency of sound (a humming noise); otherwise, the crew could not discern when a texture change occurred.

Since subsequent tests made outside the vehicle proved suspect because cuts, fills, and curves either added to or detracted from the noise levels, they were discontinued. The 36-month tests were made only inside the vehicle.

The change in noise level inside a coasting vehicle relative to the artificial-turf (control) as the surface was worn by traffic can be seen in Figure 21. The necessity of using different vehicles with different tires from one date to another requires caution when comparing data between dates, but the change relative to the control during each test date is believed to be valid.

The initial ranking from high to low noise level was transverse tine, transverse roller, transverse broom, longitudinal tine, artifical-turf (control), longitudinal broom, and artificial-turf/transverse tine. After 18 months of traffic wear, the initial trend disappeared, with all of the textures except the transverse roller being within 2 dBA of the artificial-turf (control). This variation became even less after 36 months, when all of the textures except the transverse roller were within 1 dBA of the artificial-turf (control).

Obviously, the transverse-roller texture should be ruled out as a texture candidate because of noise, but the noise-level increases of the

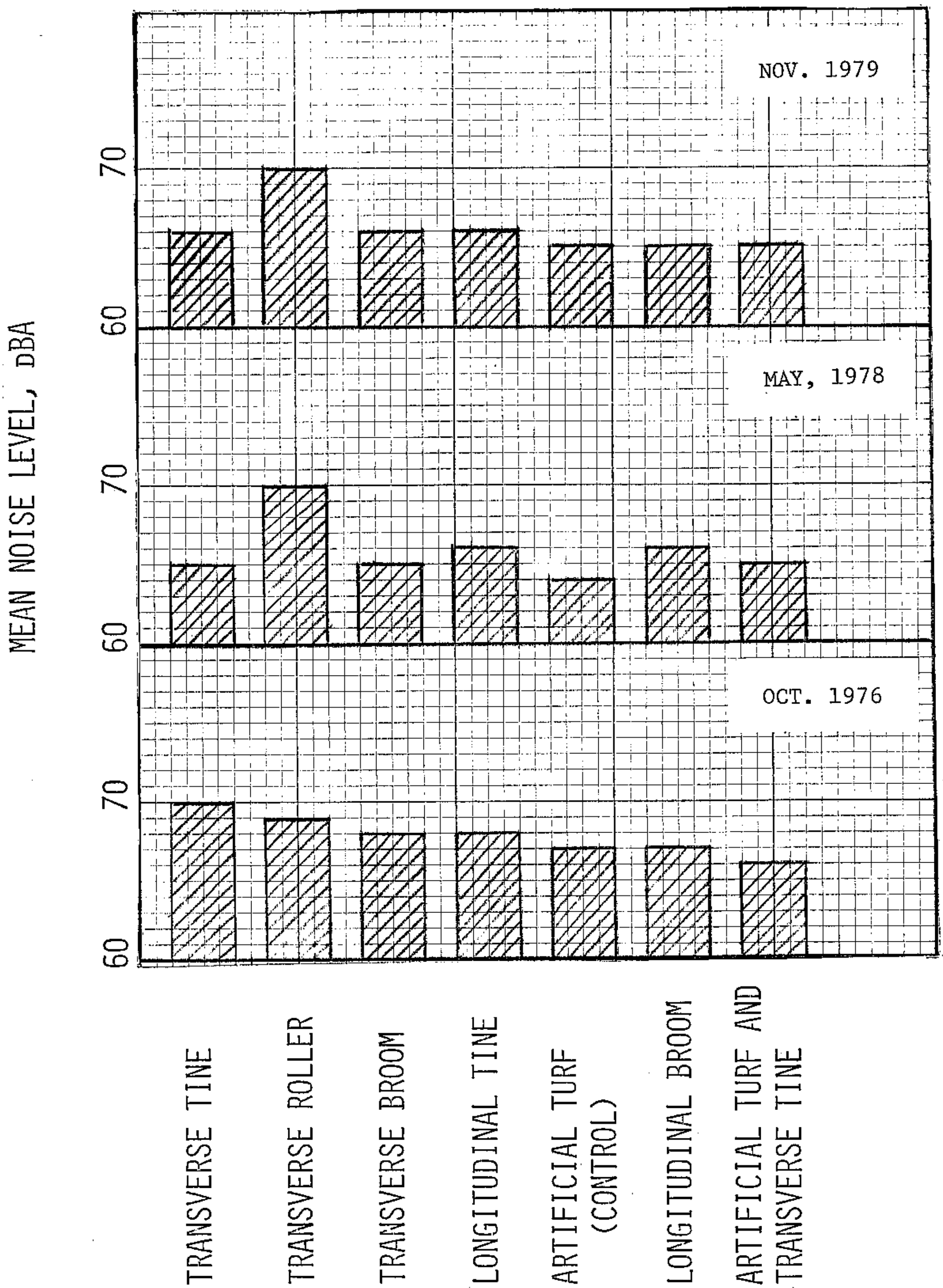


Figure 21. Comparison of mean noise level inside vehicle while coasting by texture

other textures relative to the control are insufficient to rule out their use as a final finish.

WINTER OBSERVATIONS

Observations made by the Bureau of Maintenance and District 6 Maintenance personnel during snowstorms led to the suspicion that some of the textured surfaces may be trapping snow more than others, causing a slippery condition during these storms. It was further suspected that some of the textures were causing excessive wear of snowplow blades. These winter observations were made on I-72 between Springfield and the Macon County line (about 19 miles, of which approximately 4.3 miles is constructed with the experimental textures). The balance of this pavement is finished with artificial-turf or burlap drag.

On January 13, 1977, an inspection was made of about 10 miles of both the eastbound and westbound lanes of I-72 between Springfield and Buffalo shortly after a heavy snow. Snowfall had just stopped, but a south wind of 15 to 20 mph was blowing the snow across the pavement.

A noticeable difference was observed in the greater amount of snow collecting on the artificial-turf drag and the longitudinal-tined pavement than the double burlap drag or the transverse textures. This had to do not only with the natural wind direction but also with the action of vehicle-generated wind currents. It was also difficult to determine the effect of roadside landscape features on the wind patterns and, hence, the resultant snow accumulation. In conclusion, it seemed that the natural crosswind and the vehicle-generated wind had much less effect in blowing the snow off the longitudinal-tined and artificial-turf textures than the others.

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APPENDIX A

Table of Friction Numbers at 30, 40, and 50 mph

TABLE A1

FRICTION NUMBER AT 30, 40, and 50 MPH

Texture		$\overline{FN}_{30}$		Range		$\overline{FN}_{40}$		Range		$\overline{FN}_{50}$		Range	
		Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
Art. Turf & Trans. Tine													
10-05-76		81	-	69-87	-	71	-	62-77	-	62	-	53-74	-
07-18-77		66	68	62-69	65-72	62	67	61-64	63-71	57	63	54-59	60-68
10-24-77		67	71	65-69	68-74	64	68	62-67	66-70	59	64	56-61	61-69
04-24/25-78	Reg.	63	75	61-67	73-78	56	71	54-58	69-74	53	68	52-55	66-69
04-24/25-78	Slicks	61	71	56-65	66-76	51	66	46-57	61-73	47	57	45-50	48-64
10-10-78	Reg.	57	62	55-61	61-65	54	60	52-55	58-62	50	58	48-54	56-59
10-10-78	Slicks	56	58	52-61	55-61	48	54	46-49	45-57	46	51	39-50	44-57
07-06-79	Reg.	61	62	60-64	58-65	57	63	55-58	61-64	53	61	50-55	58-65
07-06-79	Slicks	60	61	54-65	57-66	54	60	48-57	58-62	50	58	48-51	44-62
10-19-79	Reg.	55	65	52-58	63-68	53	64	51-57	60-68	50	60	48-54	57-61
10-19-79	Slicks	52	62	48-53	59-65	46	57	43-49	50-60	41	52	38-44	49-55
Trans. Tine													
10-05-76		79	-	72-86	-	65	-	59-73	-	56	-	52-61	-
07-18-77		62	65	61-64	62-70	56	58	53-59	54-60	51	56	45-53	53-62
10-24-77		67	68	64-69	64-73	61	63	57-63	60-65	55	59	53-58	54-62
04-24/25-78	Reg.	61	72	59-64	68-75	56	66	52-58	63-68	50	62	47-53	58-64
04-24/25-78	Slicks	54	61	40-61	45-72	45	60	29-55	46-66	35	49	26-42	36-59
10-10-78	Reg.	57	61	55-60	59-64	54	56	52-55	53-58	51	53	48-54	50-55
10-10-78	Slicks	47	50	42-55	36-54	39	44	23-45	31-50	35	40	18-40	31-47
07-06-79	Reg.	58	61	54-64	59-64	56	59	54-58	56-62	52	56	50-54	54-58
07-06-79	Slicks	54	56	38-61	44-64	43	53	28-52	45-58	43	43	29-49	30-53
10-19-79	Reg.	57	61	53-61	58-64	53	59	50-55	57-62	47	54	45-49	49-57
10-19-79	Slicks	47	56	39-53	43-63	41	50	27-47	34-55	36	44	25-43	29-49
Trans. Broom													
10-05-76		69	-	60-74	-	61	-	56-66	-	50	-	45-55	-
07-18-77		61	66	56-67	53-71	53	57	48-57	50-62	45	50	39-53	42-52
10-24-77		62	70	59-66	68-73	59	64	56-62	60-67	53	56	51-55	54-59
04-24.25-78	Reg.	61	73	59-62	71-77	52	65	51-54	59-69	45	61	40-47	57-63
04-24/25-78	Slicks	29	40	25-31	33-46	21	42	17-25	36-48	14	21	12-18	14-28
10-10-78	Reg.	53	61	48-55	56-64	51	56	48-53	55-57	46	51	45-47	50-53
10-10-78	Slicks	25	37	23-27	34-39	19	26	18-22	23-30	15	22	13-18	18-26
07-06-79	Reg.	55	65	53-57	63-67	52	60	49-54	58-61	48	54	44-50	51-57
07-06-79	Slicks	33	37	29-37	32-40	27	30	22-30	22-39	22	25	19-26	21-33
10-19-79	Reg.	53	62	51-55	60-64	49	60	46-53	57-62	44	54	42-46	53-56
10-19-79	Slicks	29	39	24-31	32-42	21	32	18-23	28-38	16	24	14-20	16-27

TABLE A1
FRICTION NUMBER AT 30, 40, and 50 MPH (cont'd)

Texture	$\overline{FN}_{30}$ Lane 1	$\overline{FN}_{30}$ Lane 2	Range Lane 1	Range Lane 2	$\overline{FN}_{40}$ Lane 1	$\overline{FN}_{40}$ Lane 2	Range Lane 1	Range Lane 2	$\overline{FN}_{50}$ Lane 1	$\overline{FN}_{50}$ Lane 2	Range Lane 1	Range Lane 2
Art. Turf												
10-05-76	68	-	61-78	-	55	-	42-65	-	42	-	38-48	-
07-18-77	57	64	47-63	60-67	48	55	40-53	48-60	40	46	31-47	41-50
10-24-77	63	65	62-66	61-68	52	58	48-58	54-64	49	51	42-57	49-53
04-24/25-78 Reg.	60	73	54-63	66-78	51	65	46-57	60-68	43	54	39-46	51-59
04-24/25-78 Slicks	33	48	27-39	34-61	23	38	15-33	29-48	16	24	10-25	15-34
10-10-78 Reg.	54	61	50-59	59-64	49	56	44-54	53-58	44	49	38-48	46-52
10-10-78 Slicks	31	45	24-40	35-50	21	31	18-27	23-34	16	25	13-22	18-32
07-06-79 Reg.	58	62	56-59	60-65	50	60	50-51	57-61	47	54	43-52	49-57
07-06-79 Slicks	39	46	28-51	38-52	27	35	21-34	23-41	24	26	18-30	21-34
10-19-79 Reg.	54	64	51-57	62-65	49	57	47-54	53-60	44	50	41-47	47-55
10-19-79 Slicks	29	39	25-37	29-44	21	26	17-26	22-34	16	23	9-19	17-28
Long. Tine												
10-05-76	66	-	60-72	-	53	-	46-60	-	45	-	39-57	-
07-18-77	61	62	56-67	55-66	54	54	47-60	46-60	47	48	36-53	41-56
10-24-77	64	64	61-68	62-68	58	59	52-63	55-62	54	52	49-58	46-57
04-24/25-78 Reg.	61	70	58-66	66-72	53	65	49-59	62-67	48	58	46-51	54-61
04-24/25-78 Slicks	56	64	45-61	51-74	36	48	22-50	28-58	38	41	25-45	22-59
10-10-78 Reg.	56	58	54-59	56-59	52	54	48-55	50-57	49	49	45-52	45-51
10-10-78 Slicks	54	47	49-57	39-55	40	39	33-47	31-46	35	31	24-41	23-45
07-06-79 Reg.	61	62	58-64	60-63	59	59	57-61	58-61	52	57	49-56	53-60
07-06-79 Slicks	53	59	45-58	53-62	49	50	41-55	42-55	39	43	30-45	34-59
10-19-79 Reg.	58	60	54-60	59-62	55	56	52-57	53-58	49	50	46-52	46-53
10-19-79 Slicks	48	50	37-54	42-56	41	40	30-48	28-48	34	31	24-41	21-41
Long. Broom												
10-05-76	65	-	52-76	-	52	-	43-65	-	37	-	35-41	-
07-18-77	56	60	52-61	57-64	49	51	46-52	45-56	43	46	38-49	41-48
10-24-77	62	63	58-64	60-66	57	56	55-59	54-59	50	49	46-52	47-51
04-24/25-78 Reg.	61	71	55-63	68-73	49	62	45-52	61-64	44	55	42-45	53-57
04-24/25-78 Slicks	31	42	29-33	36-47	23	28	19-40	23-30	14	17	12-16	14-21
10-10-78 Reg.	55	59	53-58	58-60	53	53	52-54	49-56	45	48	42-47	46-50
10-10-78 Slicks	35	39	31-38	35-44	21	26	18-23	22-33	20	21	15-32	18-30
07-06-79 Reg.	60	63	58-61	61-65	53	61	49-56	59-64	48	56	45-50	54-58
07-06-79 Slicks	36	38	34-39	35-44	28	26	26-31	22-29	20	21	18-23	17-23

TABLE A1

FRICTION NUMBER AT 30, 40, and 50 MPH (cont'd)

Texture		$\overline{FN}_{30}$ Lane 1	$\overline{FN}_{30}$ Lane 2	Range Lane 1	Range Lane 2	$\overline{FN}_{40}$ Lane 1	$\overline{FN}_{40}$ Lane 2	Range Lane 1	Range Lane 2	$\overline{FN}_{50}$ Lane 1	$\overline{FN}_{50}$ Lane 2	Range Lane 1	Range Lane 2
Long. Broom (cont'd)													
10-19-79	Reg.	54	63	52-55	61-65	50	55	49-51	55-56	46	51	46-47	49-54
10-19-79	Slicks	32	42	29-34	38-47	23	30	20-27	26-34	19	25	17-27	20-28
Trans. Roller													
10-05-76		43	-	40-45	-	32	-	30-35	-	26	-	23-30	-
07-18-77		56	51	52-58	48-54	46	47	44-48	42-49	41	40	39-43	37-43
10-24-77		62	59	61-63	57-60	54	54	51-58	51-56	48	45	46-50	43-48
04-24/25-78	Reg.	60	66	58-62	64-68	51	60	50-53	59-63	45	53	44-47	51-56
04-24/25-78	Slicks	38	47	35-41	44-52	32	39	26-35	33-45	20	30	16-25	24-34
10-10-78	Reg.	56	58	54-58	56-61	51	52	49-52	50-55	47	48	44-49	46-52
10-10-78	Slicks	35	43	31-38	39-46	27	35	20-33	30-38	23	28	19-26	24-31
07-06-79	Reg.	61	60	59-63	57-64	53	58	50-56	56-60	48	54	46-50	50-58
07-06-79	Slicks	43	48	42-46	45-52	35	39	29-40	36-45	29	34	24-31	27-37
10-19-79	Reg.	56	62	53-60	60-66	51	57	50-52	56-57	44	50	43-46	46-53
10-19-79	Slicks	37	46	35-39	41-50	28	38	24-31	34-42	24	32	20-28	26-36
I-55, Trans. Tines													
06-29-78		78	74	73-85	67-82	75	70	68-80	65-73	68	66	58-75	60-71
07-25-79	Reg.	55	62	50-59	53-67	51	59	46-56	52-67	49	56	46-54	50-64
07-25-79	Slicks	51	65	44-55	52-72	48	60	42-55	46-67	47	56	43-51	47-68
10-16-79	Reg.	48	62	46-51	56-66	49	60	47-51	56-62	46	-	44-48	-
10-16-79	Slicks	46	53	42-50	48-58	46	57	42-49	55-60	43	-	39-45	-